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VOL. II.

INDEX.

No. I.

STATEMENT OF THE PIG IRON USED AND PUDDLED BAR PRODUCED, ALSO THE FETTLING EMPLOYED IN EACH FURNACE.

THIS STATEMENT SHOWS THE ORDER IN WHICH THE IRON WAS WORKED, AND THE NUMBER OF CHARGES EACH TURN.

Those from which Samples for Analysis were taken are indicated by Roman Capitals.

No. 4 FURNACE.

Date and Day.	Fettling.	No. of Charges and Class of Pig.	Lbs. of Pig.	Lbs. Puddled Bar.	Remarks.
Nov. 7—Tuesday	Ilmenite for lumps, Pottery mine for melting.	1 Cleveland	600	560	
,, ,,		2 ,,	600	600	
,, ,,		Total ...	1,200	1,160	
Nov. 8—Wednesday		1 Cleveland	600	545	Fix put in.
,, ,,		2 ,,	600	631	
,, ,,		3 ,,	600	714	
,, ,,		4 ,,	600	676	A
,, ,,		5 ,,	588	672	B
,, ,,		6 Coneygree	620	700	C
,, ,,		7 ,,	600	680	D Fix.
,, ,,		Total ...	4,208	4,618	
Nov. 9—Thursday	Marbella (magnetic oxide) for lumps. Bilbao or Spanish ore (a chocolate-coloured hydrate) for melting.	1 Derbyshire	600	690	
,, ,,		2 ,,	600	640	
,, ,,		3 ,,	600	698	
,, ,,		4 ,,	600	673	
,, ,,		5 ,,	600	661	E
,, ,,		6 ,,	600	677	F
,, ,,		7 ,,	602	665	G Fix.
,, ,,		8 ,,	600	655	
,, ,,		Total ...	4,802	5,359	
Thursday Night		1 Derbyshire	600	a 657	711 } Actual weight of blooms.
,, ,,		2 ,,	600	,, 657	702
,, ,,		3 ,,	600	,, 657	749
,, ,,		4 ,,	600	,, 657	711
,, ,,		5 ,,	600	,, 657	689
,, ,,		6 ,,	600	,, 657	701
,, ,,		7 Coneygree	600	,, 628	711
,, ,,					Fix
,, ,,		Total ...	4,200	4,570	4,974
Nov. 10—Friday		1 Derbyshire	600	665	
,, ,,		2 ,,	600	630	
,, ,,		3 Crystal	600	601	Fix.
,, ,,		4 ,,	600	605	
,, ,,		5 ,,	600	605	H
,, ,,		6 ,,	600	592	I
,, ,,		7 ,,	600	615	J Fix.
,, ,,		8 Derbyshire	600	620	
,, ,,		Total ...	4,800	4,933	
Friday Night	Marbella for lumps. Bilbao for melting.	1 Cleveland	a 600	a 634	701 Fix. } Actual weight of blooms
,, ,,		2 ,,	,, 600	,, 634	701
,, ,,		3 ,,	,, 600	,, 634	717 Fix.
,, ,,		4 ,,	,, 600	,, 634	724
,, ,,		5 ,,	,, 600	,, 634	734
,, ,,		6 ,,	,, 600	,, 634	735
,, ,,		Total ...	3,600	3,804	4,312
Nov. 11—Saturday		1 Cleveland	600	695	
,, ,,		2 ,,	600	695	
,, ,,		3 Crystal	600	640	
,, ,,		4 Bar pig	600	615	
,, ,,		5 ,,	600	595	
,, ,,		6 Crystal	600	a 602	M 630 } sent home.
,, ,,		7 Bar pig	600	a 604	N 630
,, ,,		Total ...	4,200	4,446	
Nov. 13—Monday	Iron Mountain ore from Missouri.	1 Bar pig	600	627	
,, ,,		2 ,,	600	620	P R
,, ,,		3 ,,	600	a 604	658 broken.
,, ,,		4 ,,	600	590	
,, ,,		6 ,,	600	616	
,, ,,		6 ,,	600	616	
,, ,,		Total ...	3,600	3,671	
Nov. 14—Tuesday					
,, ,,					
Nov. 16—Thursday					

No. 5 FURNACE.

Date and Day.	Fettling.	No. of Charges and Class of Pig.	Lbs. of Pig.	Lbs. Puddled Bar.
Nov. 7—Tuesday		1 Cleveland	600	681
,, ,,		2 ,,	600	728
,, ,,		3 ,,	600	655
,, ,,		4 ,,	600	705
,, ,,		Total .	2,400	2,769
Nov. 8—Wednesday		1 Cleveland	600	678
,, ,,		2 ,,	600	630
,, ,,		3 ,,	597	680
,, ,,		4 ,,	600	677
,, ,,		5 Coneygree	600	670
,, ,,		6 Cleveland	600	635
,, ,,		7 Coneygree	600	666
,, ,,		Total ...	4,197	4,636
Nov. 9—Thursday		1 Derbyshire	600	657
,, ,,		2 ,,	600	675
,, ,,		3 ,,	600	672
,, ,,		4 ,,	600	676
,, ,,		5 ,,	602	665
,, ,,		6 ,,	600	660
,, ,,		7 ,,	600	660
,, ,,		8 ,,	600	660
,, ,,		Total .	4,802	5,325
Nov. 10—Friday	Iron Mountain ore.	1 Cleveland	600	539
,, ,,		2 ,,	600	575
,, ,,		3 ,,	600	683
,, ,,		4 ,,	600	605
,, ,,		5 ,,	600	605
,, ,,		6 ,,	600	575
,, ,,		7 ,,	600	595
,, ,,		8 Coneygree	600	665
,, ,,		Total ...	4,800	4,842
Nov. 11—Saturday		1 Coneygree	600	665
,, ,,		2 ,,	600	667
,, ,,		3 ,,	600	683
,, ,,		4 Crystal	600	605
,, ,,		5 ,,	600	585
,, ,,		6 ,,	600	585
,, ,,		7 ,,	600	595
,, ,,		Total	4,200	4,385
Nov. 13—Monday		1 Bar pig	600	580
,, ,,		2 ,,	600	615
,, ,,		3 ,,	600	565
,, ,,		4 ,,	600	600
,, ,,		5 ,,	600	590
,, ,,		6 ,,	600	625
,, ,,		Total ...	3,600	3,575

No. 6 FURNACE.

Date and Day.	Fettling	No. of Charges and Class of Pig.	Lbs. of Pig.	Lbs. Puddled Bar.	Remarks.
Nov. 7—Tuesday	Ilmenite lumps, Blue Billy and pottery mine for melting.	1 Cleveland	600	540	
,, ,,		2 ,,	600	615	
,, ,,		3 ,,	600	607	
,, ,,		4 ,,	600	591	
,, ,,		5 ,,	600	614	
,, ,,		6 ,,	601	611	
,, ,,		Total	3,610	3,578	
Nov. 8—Wednesday	Marbella (magnetic oxide) for lumps, Blue Billy (cupriferous pyrites residue) for melting.	1 Cleveland	600	648	
,, ,,		2 ,,	600	652	
,, ,,		3 Coneygree	600	637	
,, ,,		4 ,,	606	660	
,, ,,		5 Derbyshire	600	656	
,, ,,		6 Cleveland	600	665	
,, ,,		7 Coneygree	600	676	
,, ,,		Total ...	4,206	4,594	
Nov. 9—Thursday		1 Derbyshire	600	640	
,, ,,		2 ,,	600	680	
,, ,,		3 ,,	600	668	
,, ,,		4 ,,	600	664	
,, ,,		5 ,,	600	709	
,, ,,		6 ,,	600	685	
,, ,,		7 ,,	600	633	
,, ,,		8 ,,	600	685	
,, ,,		Total .	4,800	5,364	
Thursday Night		1 Coneygree	600	635	
,, ,,		2 ,,	600	665	
,, ,,		3 ,,	600	668	
,, ,,		4 ,,	600	660	
,, ,,		5 ,,	600	660	
,, ,,		6 ,,	600	663	Steel [illegible]
,, ,,		7 ,,	600	a 628	728
,, ,,		8 ,,	600	a 628	700
,, ,,		Total ...	4,800	5,207	
Nov. 10—Friday	Lisbon ore.	1 Coneygree	600	590	
,, ,,		2 ,,	600	680	
,, ,,		3 ,,	600	684	
,, ,,		4 ,,	600	670	
,, ,,		5 ,,	600	650	
,, ,,		6 ,,	600	683	
,, ,,		7 ,,	600	655	
,, ,,		8 ,,	600	650	
,, ,,		Total ...	4,800	5,262	
Friday Night	Lisbon or Portuguese ore, a partially decomposed magnetic oxide.	1 Coneygree	600	683	
,, ,,		2 ,,	600	661	
,, ,,		3 ,,	600	653	
,, ,,		4 ,,	600	680	
,, ,,		5 ,,	600	a 628	[illegible]
,, ,,		6 Tin plate	600	a 640	[illegible]
,, ,,		7 ,,	600	620	Steel reheated and hammer'd
,, ,,		8 Coneygree	600	620	
,, ,,		Total ...	4,800	5,188	
Nov. 11—Saturday		1 Tin plate	600	645	K } sent
,, ,,		2 ,,	600	a 610	645 } home
,, ,,		3 ,,	600	660	
,, ,,		4 ,,	600	655	L
,, ,,		5 ,,	600	620	O
,, ,,					Brickwork of door gave way.
,, ,,		Total ...	3,000	3,220	
Nov. 13—Monday	Iron Mountain ore.	1 Tin plate	600	630	
,, ,,		2 ,,	600	675	
,, ,,		3 ,,	600	610	
,, ,,		4 ,,	600	665	
,, ,,		5 ,,	600	665	
,, ,,		Total ...	3,000	3,235	
Nov. 14—Tuesday		1 Cleveland	600	629	Steel.
,, ,,		2 Coneygree	600	666	Steel.
,, ,,		Total ...	1,200	1,289	
Nov. 16—Thursday		1 Tin plate.	600	640	

OTHER FURNACES.

Date and Day.	Fettling.	No. of Charges and Class of Pig.	Lbs. of Pig.	Lbs. Puddled Bar.	Remarks.
Nov. 8—Wednesday	Iron Mountain ore.	1 Coneygree	600	620	No. 9 furnace
,, ,,		2 Derbyshire	600	595	No. 9 ,,
,, ,,		3 Coneygree	600	635	No. 10 ,,
,, ,,		4 Derbyshire	600	612	No. 10 ,,
				280	} Cobbled
,, ,,		5 Coneygree	600	350	} No. 2 ,,
				330	} caught in guide
,, ,,		6 Derbyshire	600	300	} No. 8 furnace
,, ,,		7 Coneygree	600	624	No. 1 ,,
,, ,,		8 Derbyshire	600	590	No. 1 ,,
,, ,,		Total	4,800	4,936	

NOTE.—585 lbs. Cleveland pig left unworked.

NOTE.—In all cases throughout this report the "weights of bars" means actual weight of puddled bars obtained from the reheated and rolled puddled blooms. In a few cases, marked *a*, in above table, the blooms, (*e.g.*, those made on Friday night) could not be heated and rolled into bars at once, and in these cases the actual weights of the blooms are given, and the weight of bars put into the column "puddled bar" is the average weight of all the charges of that class of iron worked into bars.

No. 2.

STATEMENT OF PIG IRON USED AND PUDDLED BARS PRODUCED.

WEIGHT OF CHARGE, 600 POUNDS.

No.	"CLEVELAND."		"CONEYGREE."		"DERBYSHIRE."		WELSH "TIN PLATE" PIG.		WELSH "BAR PIG."		WELSH "CRYSTAL."	
	Pig used. lbs.	Bars made. lbs.	Pig used. lbs.	Bars made. lbs.	Pig used. lbs.	Bars made. lbs.	Pig used. lbs.	Bars made. lbs.	Pig used. lbs.	Bars made. lbs.	Pig used. lbs.	Bars made. lbs.
1	600	560	620	700	600	690	600	640	600	615	600	601
2	600	600	600	680	600	640	600	620	600	595	600	605
3	600	545	600	628	602	698	600	645	600	604	600	605
4	600	631	600	670	600	673	600	640	600	627	600	592
5	600	714	600	660	600	661	600	660	600	620	600	615
6	600	676	600	665	600	677	600	655	600	604	600	640
7	588	672	606	637	600	665	600	620	600	590	600	602
8	600	634	600	660	600	655	600	630	600	615	600	605
9	600	634	600	676	600	657	600	675	600	615	600	585
10	600	634	600	635	600	657	600	610	600	580	600	585
11	600	634	600	665	600	657	600	665	600	615	600	595
12	600	634	600	668	600	657	600	655	600	565	...	...
13	600	634	600	660	600	657	600	640	600	600	...	...
14	600	681	600	660	600	657	...	...	600	590	...	...
15	600	728	600	663	600	665	...	...	600	625	...	...
16	600	655	600	628	600	630	...	...	...	...	...	...
17	600	705	600	628	600	620	...	...	...	...	...	...
18	600	678	600	590	602	657	...	...	...	...	...	...
19	600	630	600	680	600	675	...	...	...	...	...	...
20	597	680	600	684	600	672	...	...	...	...	...	...
21	600	677	600	670	600	676	...	...	...	...	...	...
22	600	635	600	650	600	665	...	...	...	...	...	...
23	600	539	600	683	600	660	...	...	...	...	...	...
24	600	575	600	655	600	660	...	...	...	...	...	...
25	600	683	600	650	600	660	...	...	...	...	...	...
26	600	605	600	683	600	656	...	...	...	...	...	...
27	600	605	600	680	600	640	...	...	...	...	...	...
28	600	575	600	664	600	680	...	...	...	...	...	...
29	600	595	600	653	600	668	...	...	...	...	...	...
30	600	540	600	665	600	664	...	...	...	...	...	...
31	600	615	600	667	600	709	...	...	...	...	...	...
32	600	607	600	683	600	685	...	...	...	...	...	...
33	609	614	600	628	600	633	...	...	...	...	...	...
34	600	591	600	620	600	685	...	...	...	...	...	...
35	600	611	600	660	600	595	...	...	...	...	...	...
36	601	648	600	620	600	612	...	...	...	...	...	...
37	600	652	600	635	600	630	...	...	...	...	...	...
38	600	665	600	630	600	590	...	...	...	...	...	...
39	600	695	600	624	...	...	...	...	...	...	...	...
40	600	695	...	...	...	...	...	...	...	...	...	...
41	600	629	...	...	...	...	...	...	...	...	...	...
	24,595	26,010	23,426	25,563	22,804	24,988	7,800	8,355	9,000	9,060	6,600	6,630

Total Pig used.	Bars made.	Pig to a ton of Bars.
94,225 lbs.	100,606 lbs.	18 cwt. 2 qr. 25 lbs.

No. 3.

STATEMENT OF YIELD OF PUDDLED BAR FROM PIG IRON.

	Pig used. lbs.		Bars made. lbs.		Pig to a ton of Bars. cwts.	qrs.	lbs.
			CLEVELAND.				
	24,595	...	26,010	...	18	3	17
			CONEYGREE.				
	23,426	...	25,563	...	18	1	8
			DERBYSHIRE.				
	22,804	...	24,988	...	18	0	27
			WELSH. Tin Plate Pig.				
	7,800	...	8,355	...	18	1	20
			WELSH. Bar Pig.				
	9,000	...	9,060	...	19	3	13
			WELSH. Crystal.				
	6,600	...	6,630	...	19	3	17
Total,	94,225	...	100,606	...	18	2	25

ES.

E WEEK (in Lbs.)

D	rap.	Tap Cinder produced.	Coal.	Pig.	Puddled Bar.
November	5	...	3,050 Hocking Valley.	...	...
„		548	8,219	1,200	1,160
			1,710		
„	2	1,261	3,721 (P.)	4,208	4,618
Total for	7	1,809	16,700	5,408	5,778
Novembe	8	...	8,138	4,802	5,359
„	9	2,003	4,160	4,200	4,570
„		1,000	8,770	4,800	4,933
„	1	...	...	3,600	3,804
„	5	2,634	3,740	4,200	4,446
Total for	3	5,637	24,808	21,602	23,112
Totals fo	0	7,446	41,508	27,010	28,890
Novembe	09	...	3,170 Hocking Valley.	...	...
	35	...	9,190	3,610	3,578
„			1,650		
„	94	...	4,380 (P.)	4,206	4,594
Total for	38	4,234	18,390	7,816	8,172
Novemb	17	(See Note b.)	762		
	98		8,904	4,800	5,364
„	45	...	4,510	4,300	5,207
„	96	...	6,730	4,800	5,262
„	60	...	1,470	4,800	5,188
„		...	6,608	3,000	3,220
Total fo	16	...	28,984	22,200	24,241
Totals f	54	...	47,374	30,016	32,413
Total m	84	...	88,882	57,026	61,303
Used in pig u	..	...	...	37,199 585 (c)	...
Total m land.	..	...	...	94,810	...

lbs.

pig was not worked.

No. 4.

EXPERIMENTAL PUDDLING FURNACES.

ABSTRACT SHOWING MATERIALS USED AND PRODUCED FOR ONE WEEK (IN LBS.)

No. 4 FURNACE.—THREE DAY TURNS.

DATE AND DAY.	Iron Mountain Ore.	Blue Billy.	Pottery Mine.	Ilmenite.	Bilbao Spanish Ore.	Lisbon Ore.	Marbella.	Squeezer and Roll Cinder.	Iron Scrap.	Tap Cinder produced.	Coal.	Pig.	Puddled Bar.
November 6—Monday	1,237	1,168	...	...	926	...	...	...	...	...	3,050 } Hocking Valley.	...	...
„ 7—Tuesday	...	...	2,655	3,018	...	...	...	1,329	195	548	8,219 1,710 } Hocking Valley.	1,200	1,160
„ 8—Wednesday	...	...	797	...	...	...	...	3,812	92	1,261	3,721 (P.)	4,208	4,618
Total for three days	1,237	1,168	3,452	3,018	926	...	...	5,141	287	1,809	16,700	5,408	5,778
FIVE CONSECUTIVE TURNS (DAY AND NIGHT.)													
November 9—Thursday	...	...	...	...	670	...	1,380	2,614	108	...	8,138	4,802	5,359
„ „ Night	...	...	...	...	370	...	...	2,731	129	2,003	4,160	4,200	4,570
„ 10—Friday	...	...	...	...	1,845	...	500	1,260	...	1,000	8,770	4,800	4,933
„ „ Night	...	...	...	...	513	...	...	1,379	41	...	...	3,600	3,804
„ 11—Saturday	...	...	...	...	315	...	...	13	165	2,634	3,740	4,200	4,446
Total for five shifts	...	...	...	...	3,711	...	1,880	7,997	443	5,637	24,808	21,602	23,112
Totals for whole week	1,237	1,168	3,452	3,018	4,637	...	1,880	12,138	730	7,446	41,508	27,010	28,890
No. 6 FURNACE.—THREE DAY TURNS.													
November 6—Monday	Initial Lining.	216	350	504	...	...	...	(See Note *a.*)	309	...	3,170 } Hocking Valley.	...	...
„ 7—Tuesday	...	940	...	...	...	...	1,610	...	235	...	9,190 1,650 } Hocking Valley.	3,610	3,578
„ 8—Wednesday	...	1,334	...	...	...	...	...	...	94	...	4,380 (P.)	4,206	4,594
Total for three days	...	2,490	350	504	...	...	1,610	...	638	4,234	18,390	7,816	8,172
FIVE CONSECUTIVE TURNS (DAY AND NIGHT.)													
November 9—Thursday	...	485	...	...	...	...	1,100	(See Note *a.*)	117	(See Note *b.*)	762 8,904	4,800	5,364
„ „ Night	...	...	...	...	430	...	...	...	198	...	4,510	4,300	5,207
„ 10—Friday	...	743	...	...	...	941	...	...	245	...	6,730	4,800	5,262
„ „ Night	...	...	...	...	...	4,124	...	...	96	...	1,470	4,800	5,188
„ 11—Saturday	...	...	...	...	...	1,111	...	...	160	...	6,608	3,000	3,220
Total for five shifts	...	1,228	...	...	430	6,176	1,100	...	816	...	28,984	22,200	24,241
Totals for whole week	...	3,718	350	504	430	6,176	2,710	...	1,454	...	47,374	30,016	32,413
Total material on both furnaces	1,237	4,886	3,782	3,522	5,067	6,176	4,590	...	2,184	...	88,882	57,026	61,303
Used in following week, and also pig used in No. 5 this week	...	...	...	836	338	...	...	...	...	...	...	37,199 585 (*c*)	...
Total material brought from England	...	4,886	3,782	4,358	5,405	6,176	4,590	...	...	...	...	94,810	...

(*a.*) Squeezer slag (cinder) used in No. 5 and 6 furnaces to puddle 84 charges, 30,365 lbs.

(*b.*) Tap cinder from 5 and 6 furnaces (60 charges), 14,550 lbs. (*c.*) 585 lbs. Cleveland pig was not worked.

No. 5.

YIELDS OF FETTLING, &c., DEDUCED FROM "ABSTRACTS OF MATERIALS USED."

No. 4 FURNACE.

	Lbs.	Lbs.
Initial lining required		
Iron ore		3,331
Thick lime cream	510	
Squeezer slag, to glaze lining	475	
Interior lining or fix required		
Pottery mine		1,292
Ilmenite lumps		1,512
Iron scrap	110	
Total ore used for lining		6,135
Coal used for drying and fixing furnace		6,998

No. 6 FURNACE.

Initial lining.

An old one of Iron Mountain ore, worked as bare as possible

Coal used for fixing and keeping in on Monday night 3,170

RESULTS OF FIVE CONSECUTIVE SHIFTS, WORKED IN No. 4 FURNACE.

Puddled bars made.
23,112 lbs.

Ore used.		Ore used per 2,240 lbs. puddled bar.
Bilbao	3,711 lbs.	cwt. 4, qrs. 3, lbs. 9
Marbella	1,880 ,,	
	5,591 ,,	

Scrap used.	Scrap per ton puddled bar.
443 lbs.	42 lbs.

Squeezer slag used.	Squeezer slag per ton puddled bar.
lbs. 7,997	cwt. 6, qrs. 3, lbs. 19

Tap cinder produced.	Tap cinder per ton puddled bar.
lbs. 5,637	cwts. 4, qrs. 3, lbs. 14

FIVE CONSECUTIVE SHIFTS IN No. 6 FURNACE.

Puddled bar made.
24,241 lbs.

Ore used.		Ore used per ton puddled bar.
Blue Billy	1,228 lbs.	cwts. 7, qrs. 1, lbs. 13
Bilbao	430 ,,	
Lisbon	6,176 ,,	
Marbella	1,100 ,,	
	8,934 ,,	

Scrap used.	Scrap per ton puddled bar.
816 lbs.	75 lbs.

NOTE.—The fettling used in No. 6 Furnace is excessive, in consequence of the Lisbon ore being unsuitable for the purpose. Although containing no more silica than Bilbao and Marbella, its soft and irregular nature causes it to crumble and waste away. No. 6 Furnace did not work as well as No. 4 at any time.

No. 6.

STATEMENT OF COAL USED AT Nos. 4 AND 6 DURING THE WEEK ENDING NOV. 11, 1871.

No. 4.

Coal used. lbs.		Bars made. lbs.		Coal to a ton of bars. cwts.	qrs.	lbs.
41,508	... ...	28,890	... ...	28	2	24

No. 6.

47,374	... ...	32,413	... ...	29	0	25

Total Coal used. lbs.		Bars made. lbs.		Coal to a ton of bars. cwts.	qrs.	lbs.
88,882	... ...	61,303	... ...	29	0	0

NOTE 1.—The coal includes that consumed for lighting up and fixing No. 4 from the bar plates, and that used for keeping furnaces alight on Tuesday and Wednesday nights. In fact, all the coal used at the two furnaces named.

NOTE 2.—In addition to the coal used at the puddling furnaces, there is to be added the coal consumed in reheating, which averages about 5 cwts. to the ton of puddled bars, one furnace reheating about 16 tons per shift.

No. 7.

STATEMENT OF CONSUMPTION OF COAL AT Nos. 4, 5, AND 6, FOR PUDDLING, FOR FIVE CONSECUTIVE SHIFTS AT Nos. 4 AND 6, AND THREE SHIFTS FOR No. 5, THE LATTER DOING NOTHING FOR TWO NIGHTS.

	Coal used. lbs.		Bars made. lbs.		Coal to a ton of Bars. cwts.	qrs.	lbs.
			No. 4 Furnace.				
	24,808	...	23,112	...	21	1	24
			No. 6 Furnace.				
	28,152	...	24,241	...	23	0	25
			No. 5 Furnace.				
	15,150	...	14,552	...	20	3	8
Total	68,110	...	61,905	...	22	0	0

NOTE.—The above experiment was made in order to show what coal was used during the actual puddling of the iron, as in another statement will be found included the coal used for keeping the furnaces alight during the night, as well as lighting up and fixing.

No. 8.

STATEMENT OF YIELDS FROM PUDDLED BARS TO RAILS AND OTHER CLASSES OF FINISHED IRON.

	5″ Blooms hammered. lbs.	$1\frac{3}{8}''$ Billets made. lbs.	Bloom to a ton of billets. cwts.	qrs.	lbs.
Coneygree	145	139	20	3	12
T. P.	154	147	20	3	21
	299	286	20	3	18

	7″ puddled bars. lbs.	Plates, including Shearings. lbs.	Bars to a ton of plates. cwts.	qrs.	lbs.
Coneygree	296	278	21	1	6
W. B. P.	288	260	22	0	17
Cleveland	300	273	21	3	25
Derby	300	279	21	2	0
T. P.	300	283	21	0	22
	1,484	1,373	21	2	12

	Billets. lbs.	Wire rods. No. 4 gauge. lbs.	Billets to a ton of rods. cwts.	qrs.	lbs.
Coneygree	115	97	23	2	23
T. P.	123	109	22	2	7
	238	206	23	0	11

	7″ puddled bars. lbs.	Rails, including ends. lbs.	Bars to a ton of rails. cwts.	qrs.	lbs.
Coneygree	4,411	4,088	21	2	8
Cleveland	4,409	4,099	21	3	4
Derby	4,384	4,067	21	2	6
Tin Plate	2,974	2,756	21	2	9
Crystal	1,442	1,319	21	3	12
Bar pig	715	665	21	2	0
	18,335	16,944	21	2	16

NOTE.—All the above rolled well, except some of the rails. The Coneygree, Cleveland, and tin plate rolled off at one heat, and were sound in head and flange. The Derby, Crystal, and bar pig made good heads, but tore up in the flange. Draught of rolls irregular and severe.

No. 9.

STATEMENT OF REPAIRS DONE TO THE 9 FURNACES AT THE CINCINNATI RAILWAY IRON WORKS, WEEK ENDING NOVEMBER 11TH, 1871.

	lbs.
No. 6.—Replacing a ring at flue end ... ... (Two men, half-a-day each.)	384
No. 6.—Replacing a ring for elbow joint ... ... (Two men, half-a-day each.)	338
No. 1.—One frame replaced at elbow joint	80
No. 10.—Putting in four rivets in flue ring.	

NOTE.—The only brickwork to repair is that over and around the grate, and that in the elbow-joint or flue. The repairs to brickwork, as compared with an ordinary furnace, are exceedingly small. In other respects, the repairs are small, so far as we could judge by three weeks' observation.

STAT NATI RAILWAY IRON WORKS,

1TH, 1871.

AKING A TOTAL OF TEN.

No. 3.*

18	s.	Pig Charged. Lbs.	Bars Made. Lbs.
Monday,		4,200	4,745
Tuesday,		...	...
Wednesd		...	...
Thursday		...	...
Friday		...	...
Saturday		...	...
		...	...
Total f		4,200	4,754

orked but one shift.

No. 6.

187	Pig Charged. Lbs.	Bars Made. Lbs.	
Monday,	4,800	4,890	A
Tuesday,	3,610	3,578	A
Wednesda	4.206	4,594	A
Thursday,	4,800	5,364	A
Friday,	4,800	5,262	A
Saturday,	3,000	3,220	A
Total fo	25,216	26,908	
Thursday	4,800	5,207	A
Friday Ni	4,800	5,188	A
To	9,600	10,395	
Aggrega	34,816	37,303	

No. 10.

187	Pig Charged. Lbs.	Bars Made. Lbs.	
Monday, 1	4.800	4,850	Short of Coal.
Tuesday,	4.800	5,010	
Wednesda	3,600	3,600	
Thursday,	4,800	4,955	
Friday,	1,800	1,810	
Saturday,	4,800	4,935	
Total fo	24,600	25.160	

NOT io is not navigable. The returns on this g all material in and out.

Pig to a ton of Bars.
Cwts. Qrs. Lbs.
19 0 20

No. 10.

STATEMENT OF PUDDLED BARS MADE, AND NUMBER OF HEATS MADE AT THE CINCINNATI RAILWAY IRON WORKS, AT ALL THEIR FURNACES, FOR THE WEEK ENDING NOVEMBER 11TH, 1871.

THERE WERE NINE FURNACES ERECTED FIT FOR WORK, AND ONE FURNACE PARTIALLY ERECTED, MAKING A TOTAL OF TEN.

No. 1.

1871.	No. of Heats.	Pig Charged. Lbs.	Bars made. Lbs.	
Monday, Nov. 6th	8	4,800	4,775	
Tuesday, „ 7th	8	4,800	4,900	
Wednesday „ 8th	7	4,200	4,249	
Thursday „ 9th	8	4,800	4,937	
Friday „ 10th	3	1,800	1.800	Short of Coal.
Saturday „ 11th	8	4,800	4,800	
Total for Week ..	42	25,200	25,461	

No. 2.

No. of Heats.	Pig Charged. Lbs.	Bars made. Lbs.	
7	4,200	3,800	
8	4,800	4,725	
7	4,200	4,240	
7	4,200	4,542	
3	1,800	1,800	Short of Coal.
8	4,800	5,303	
40	24,000	24,410	

No. 3.*

No. of Heats.	Pig Charged. Lbs.	Bars Made. Lbs.
7	4,200	4,745
...	...	...
...	...	...
...	...	...
...	...	...
...	...	...
7	4,200	4,754

* No. 3 was the spare Furnace kept for an emergency, should anything befall one of the other Furnaces. It worked but one shift.

No. 4.

1871.	No. of Heats.	Pig Charged. Lbs.	Bara made. Lbs.	
Monday, Nov. 6th	...	...	...	
Tuesday, „ 7th	2	1,200	1,160	A
Wednesday „ 8th	7	4,208	4,618	A
Thursday, „ 9th	8	4,802	5.359	A
Friday, „ 10th	8	4.800	4,933	A
Saturday, „ 11th	7	4.200	4,446	A
Total for Week...	32	19.210	20,516	
Thursday Night......	7	4,200	4,570	A
Friday Night.........	6	3,600	3,804	A
Total.........	13	7,800	8,374	
Aggregate Total...	45	27,010	28,890	

No. 5.

No of Heats.	Pig Charged. Lbs.	Bars Made. Lbs.	
8	4,800	5,070	A
3 } 7	1,800	1,850	A
4 }	2,400	2,769	A
7	4,197	4,636	A
8	4,802	5,325	A
8	4,800	4,842	A
7	4,200	4,385	A
45	26,999	28.877	

No. 6.

	No. of Heats.	Pig Charged. Lbs.	Bars Made. Lbs.	
	8	4,800	4,890	A
	6	3,610	3,578	A
	7	4.206	4,594	A
	8	4,800	5,364	A
	8	4,800	5,262	A
	5	3,000	3,220	A
	42	25,216	26,908	
Thursday Night	8	4,800	5,207	A
Friday Night...	8	4,800	5,188	A
Total......	16	9,600	10,395	
Aggregate Total	58	34,816	37,303	

No. 8.

1871.	No. of Heats.	Pig Charged. Lbs.	Bars made. Lbs.	
Monday, Nov. 6th	8	4,800	4,740	
Tuesday, „ 7th	8	4,800	5,225	
Wednesday „ 8th	8	4,800	4,790	
Thursday, „ 9th	7	4,200	4,435	
Friday, „ 10th	3	1,800	1,770	Short of Coal
Saturday, „ 11th	8	4,800	4,905	
Total for Week...	42	25,200	25,865	

No. 9.

No. of Heats.	Pig Charged. Lbs.	Bars Made. Lbs.
8	4,800	4,985
8	4,800	4,945
8	4,800	4,790
7	4,200	4,205*
...	...	...
...	...	...
31	18,600	18,925

No. 10.

No. of Heats.	Pig Charged. Lbs.	Bars Made. Lbs.	
8	4 800	4,850	
8	4.800	5,010	
6	3,600	3,600	
8	4,800	4,955	
3	1,800	1,810	Short of Coal.
8	4,800	4,935	
41	24,600	25.160	

* The puddler here left off in order to work at night, at No. 7.

NOTES.—It will be observed that on Friday, the works suffered from a coal famine, a matter of frequent occurrence here when the Ohio is not navigable. The returns on this sheet were taken from the books of the Company. Those portions marked A are what we specially looked after, weighing all material in and out.

TOTAL OF PIG CHARGED AND BARS MADE.

No. of Heats.	Pig used.	Bars made.	Pig to a ton of Bars.
351	210,625 lbs.	219,636 lbs.	Cwts. 19 Qrs. 0 Lbs. 20
	Tons. 94 Cwts. 0 Qrs. 2 Lbs. 9	Tons. 98 Cwts. 1 Qrs. 0 Lbs. 4	

No. II.

STATEMENT OF RESULTS OBTAINED WITH ROTARY FURNACE AT OTHER WORKS.

No. 1.—Jones, Laughlin, & Co., Pittsburgh. Mr. Jones very kindly had the furnace put in order and worked a few heats specially for us, from American iron of various classes. The results obtained were as follows:—

1st charge. "Douglas iron" grey pig, made from $\frac{2}{3}$ Lake Superior, $\frac{1}{3}$ Lake Champlain ore and raw coal; pig, 520 lbs.; bloom made under hammer, 520 lbs. 210 lbs. of this charged into heating furnace gave 196 lbs. merchant bar.

2nd charge. "Eliza iron" mottled and close grey, made from all Lake Superior ore with coke. Charge put in at 10·45, brought out at 11·55. This ball was too hot in centre, and cold on outside, and went to pieces under hammer.

3rd charge. "Douglas iron." Mr. J. A. Jones caused this heat to be worked in a slightly different manner, whereby the quality was much improved, but the yield was not so good—515 lbs. pig gave 433 lbs. hammered blooms. The iron from this heat stood the most severe hot and cold test admirably.

From the books of the company we extracted the following results of charges worked in the rotary furnace:—

Results.	Charges.	Pig charged.	Hammered Bloom.	Iron Turnings.	Ore.
April 8	6	4,200	4,305	115	600
,, 21	6	4,220	4,270	310	715
,, 22	4	2,825	2,792	135	742
,, 24	5	3,540	3,771	No turnings.	485
,, 25	5	3,600	3,722	160	800
,, 26	6	4,240	4,127	235	762
,, 27	5	3,585	3,575	240	910
,, 28	5	3,560	3,698	230	915
,, 29	5	3,567	3,809	240	705
May 1	4	2,850	3,010	140	980
,, 2	5	3,550	3,611	135	718
	56	39,737	40,690	1,940	8,332

Yields per ton hammered blooms.

Pig iron to a ton of blooms.			Iron turnings.		Iron ore.		
cwts.	qrs.	lbs.	qrs.	lbs.	cwts.	qrs.	lbs.
19	2	3	3	22	4	0	9

No 2.—At the Roane Iron Works, Chattanooga, we watched the working of the furnaces for several days, and found that good results were being produced from an inferior quality of iron. We had several rail piles made from puddled bars alone, and all the rails were clean and good, and showed a good fibrous fracture.

The books at these works showed that 2,820 lbs. coal were required per 2,240 lbs. puddled bar at the puddling furnaces, as an average over the three months August, September, and October. This includes the coal required for keeping the furnaces in during the night, as they are only worked single shift.

Description of Drawings of Danks's Improved Revolving Puddling Furnace.

No. 1 is a sectional elevation of the furnace, showing the fire-grate, wind jet pipes which convey fan blast into the fire chamber over the fire, for the purpose of effecting as perfect a combustion of the gases as is desirable, producing a quick and intense heat. The bridge is shown, with the plate having water pipes passing through it, protected on the one side with firebrick, and on the other with fettling. The revolving chamber is also shown, with the tapping hole, carrying rollers, also the ends of bed plates, and movable piece with stopper hole, which latter is suspended from an overhead track.

No. 2 is an end view, showing the arrangement of bed plate, carrying rollers, and gear wheels, also an end view of the revolving chamber, with a section of fettling; a portion of the fire bridge is also shown.

No. 3 is a plan, as seen from above, showing the arrangement of air pipes for the production of gas, and the jet pipes for the combustion of gas; a portion of the grate bars is shown, also a portion of the fire bridge. A bridge ring or collar is shown, having a water pipe cast in it, also the revolving chamber, with gear wheels, movable piece, stationary flue, and section of chimney stack.

No. 4 presents a front view of the furnace, showing the movable piece, with its stopper hole, props, and water pipes; rods and swivels for suspending the movable piece; stationary flue, and chimney stack.

No. 5 are diagrams of forks for handling puddled balls and blooms.

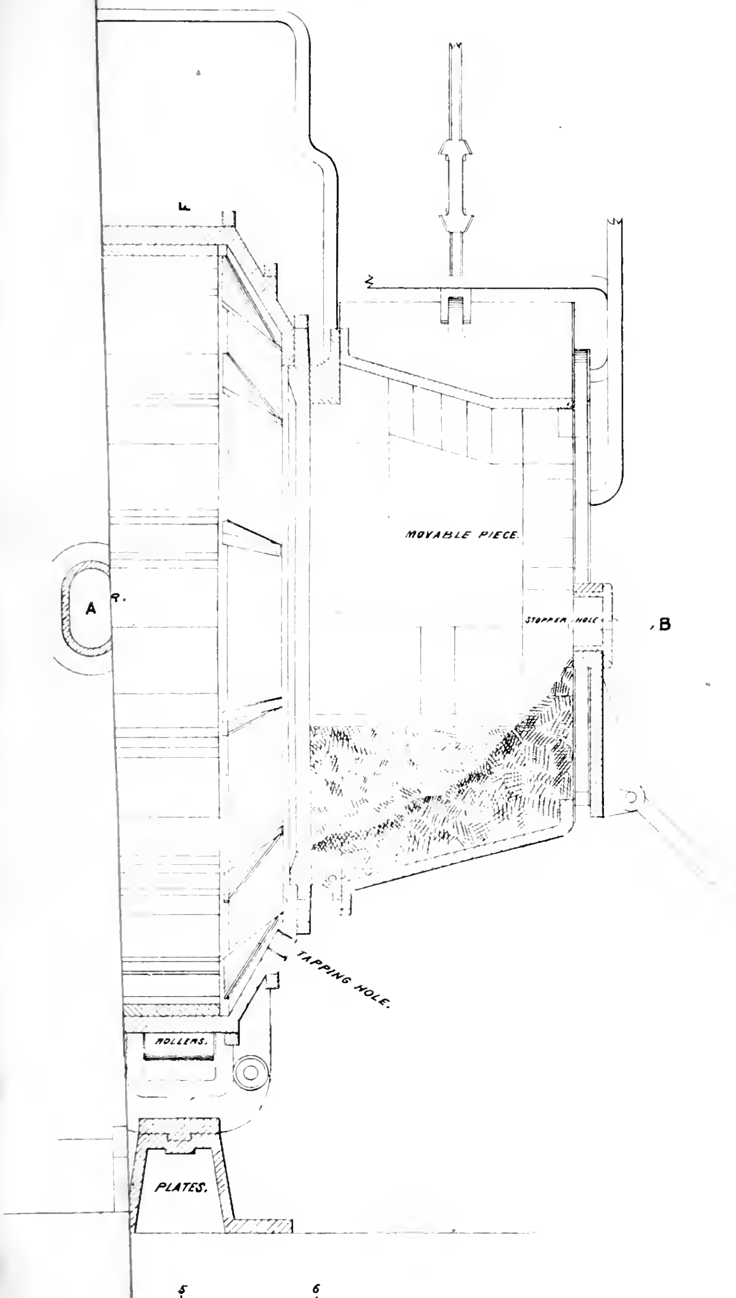
Squeezer.

No. 6 is a front sectional elevation, showing a section of the steam hammer or ram; a section of the squeezer cam and roll; housings, bed-plate, and driving gear wheels.

No. 7 is a section of squeezer, showing the squeezer cam, rolls, the head of steam ram, housing, and the ends of bed-plates.

NE

No. 1

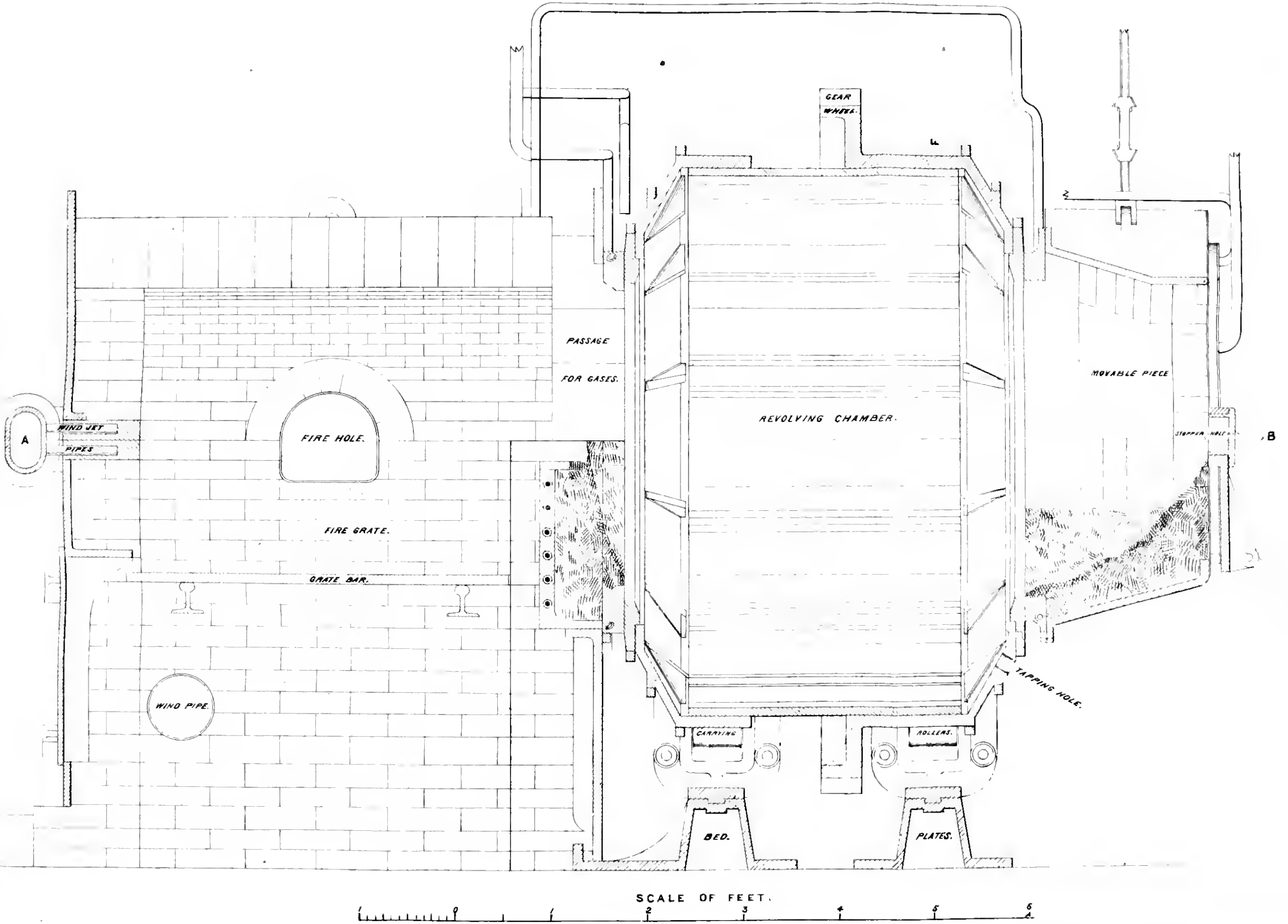


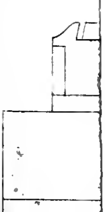
MOVABLE PIECE.
A
STOPPER HOLE
B
TAPPING HOLE.
ROLLERS.
PLATES.
5
6

DANKS'S ROTARY PUDDLING MACHINE.

SECTIONAL ELEVATION

No. 1



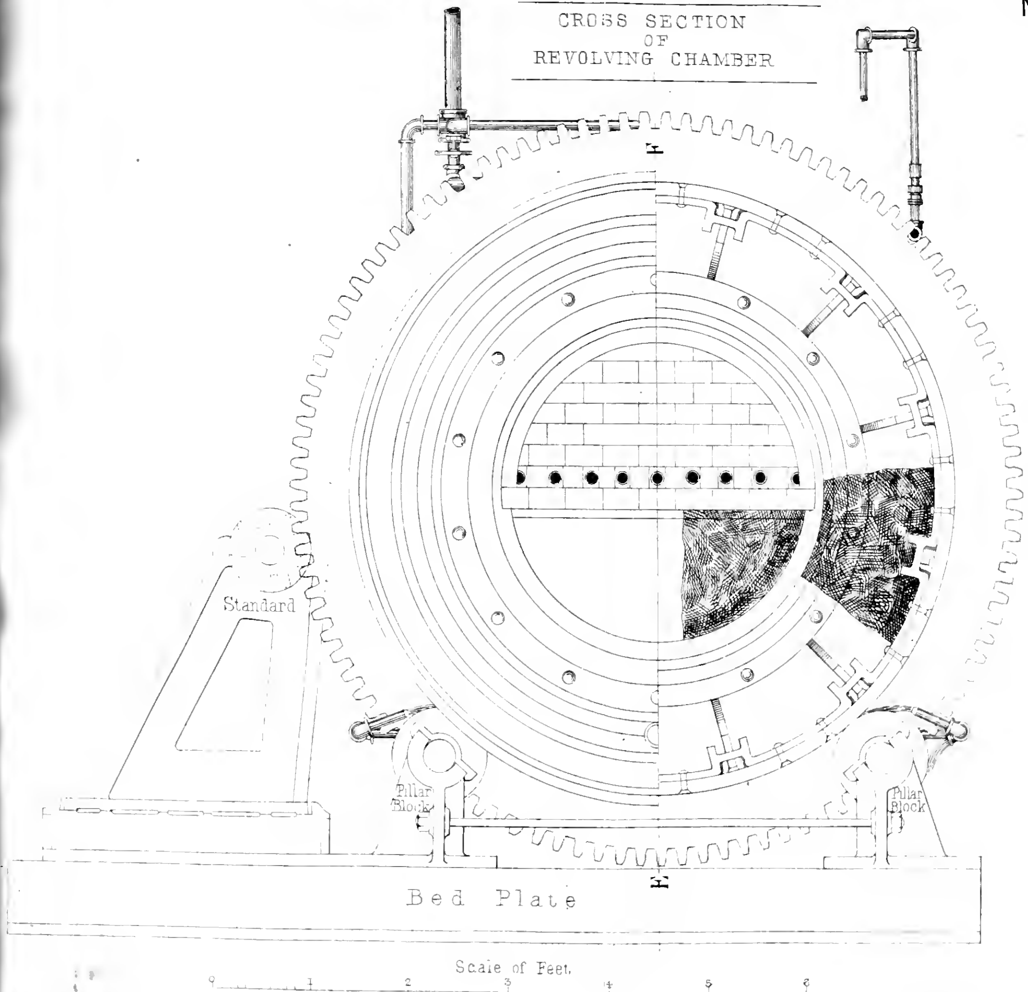


ort of Puddling

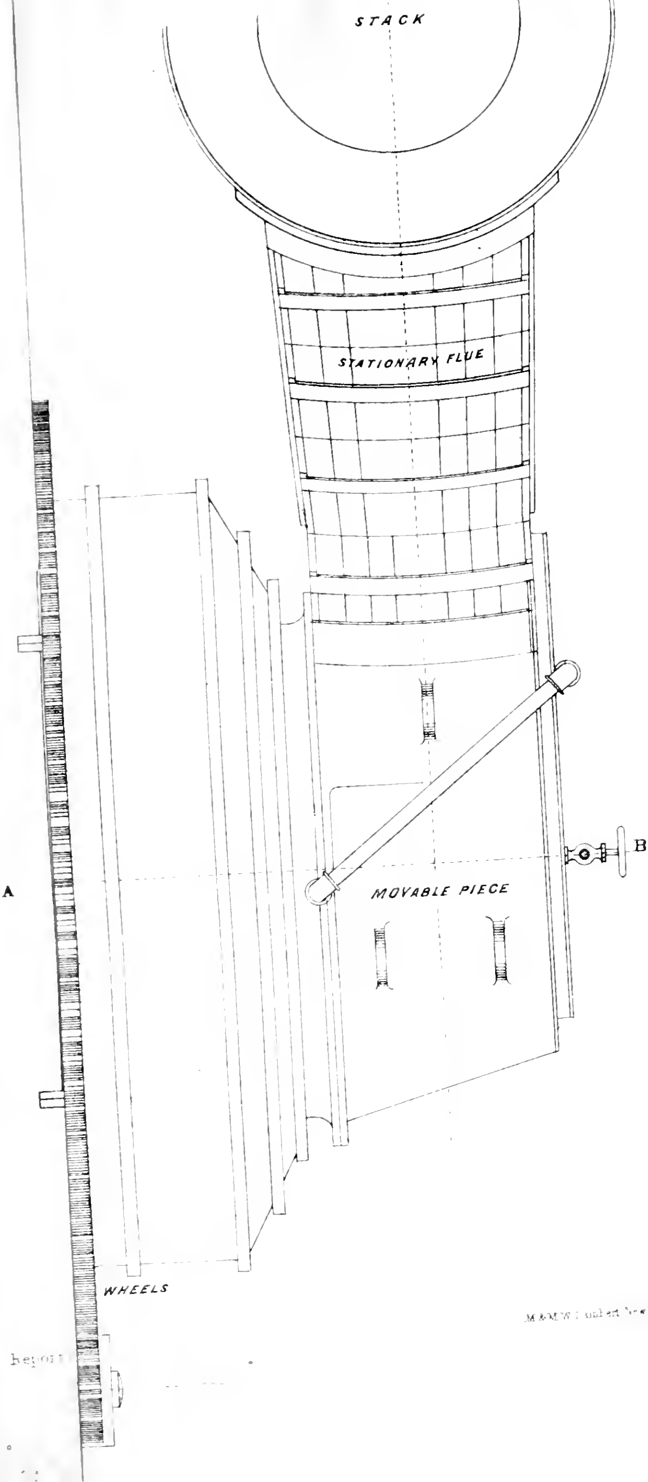
DANKS'S ROTARY PUDDLING MACHINE.

No. 2.

CROSS SECTION OF REVOLVING CHAMBER



No. 3.



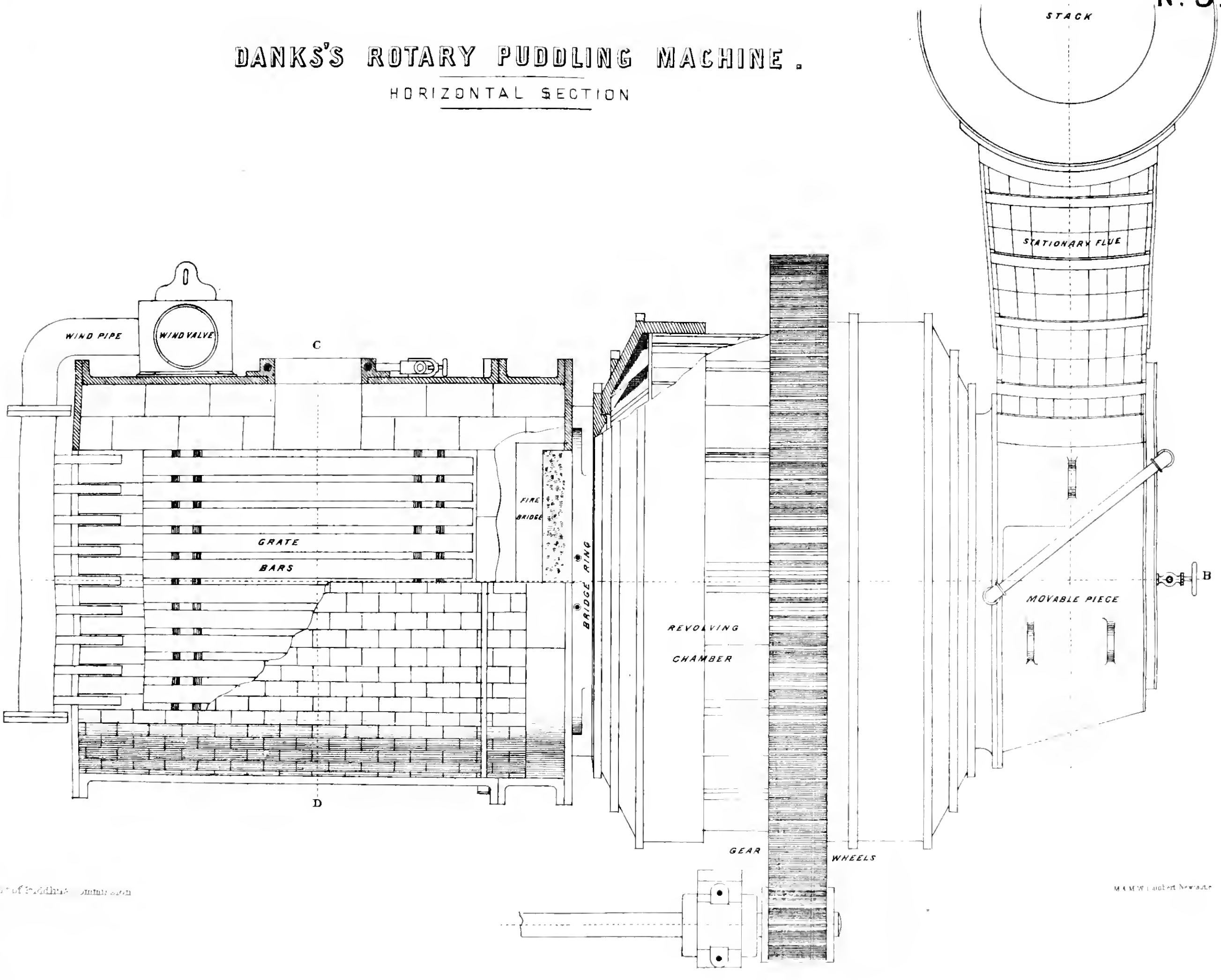
M & M W Lambert Newcastle

Report

No. 3.

DANKS'S ROTARY PUDDLING MACHINE.

HORIZONTAL SECTION

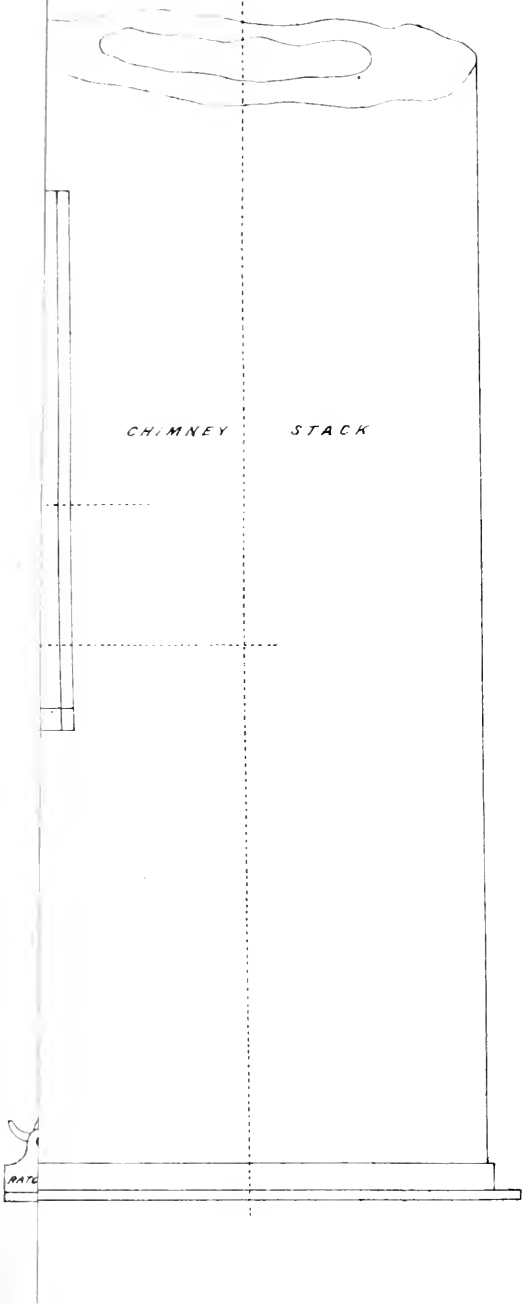


Report of Puddling Commission

M & M W Lambert Newcastle

E.

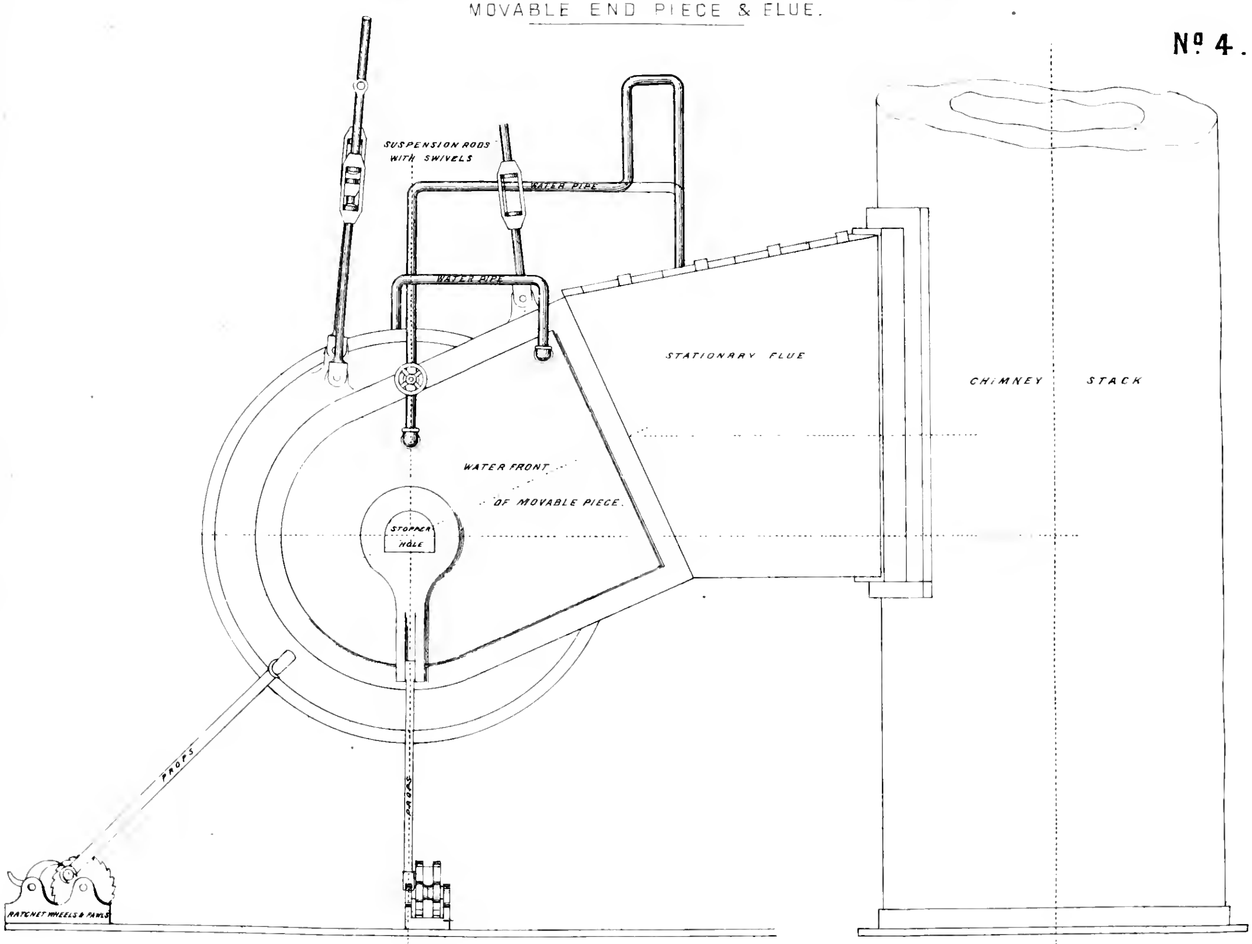
Nº 4.



DANKS'S ROTARY PUDDLING MACHINE.

MOVABLE END PIECE & FLUE.

Nº 4.

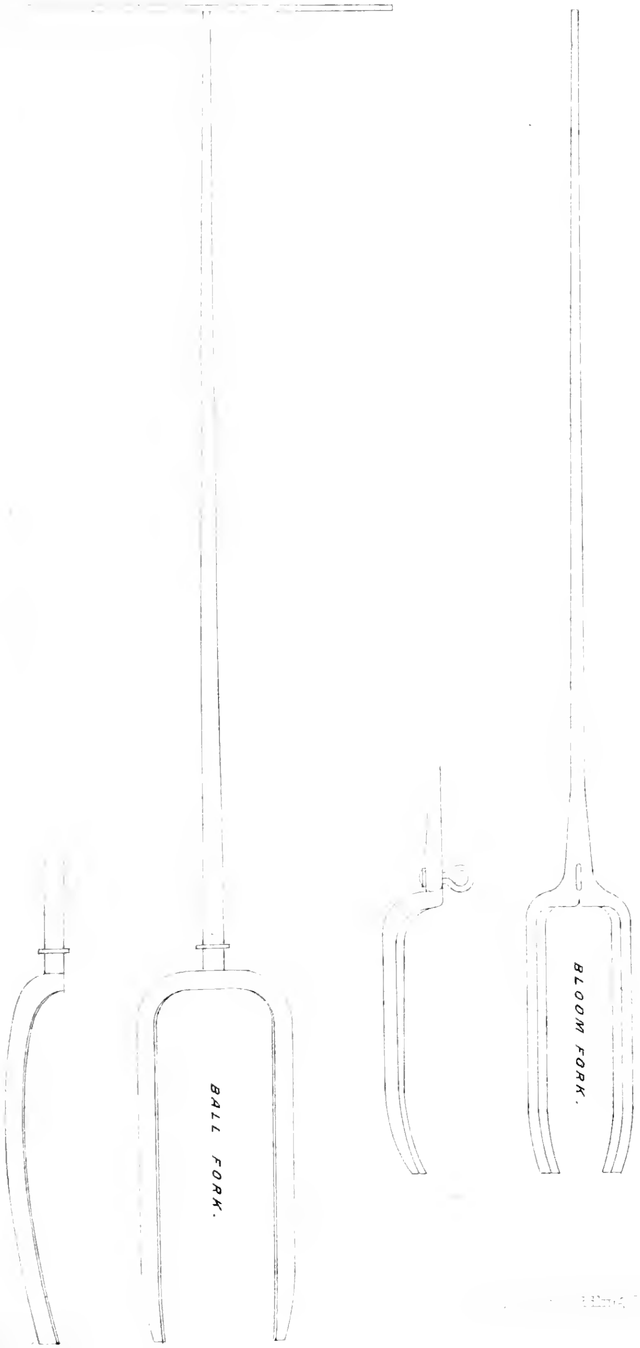


M & M W Lambert Newcastle

DANKS'S ROTARY PUDDLING MACHINE.

DIAGRAMS OF FORKS

No. 5



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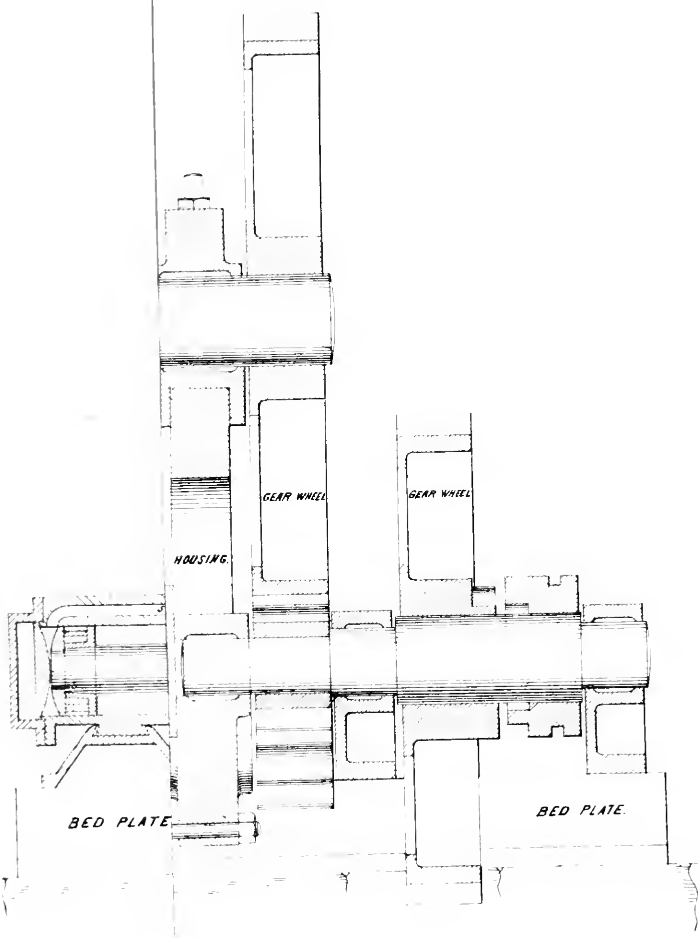
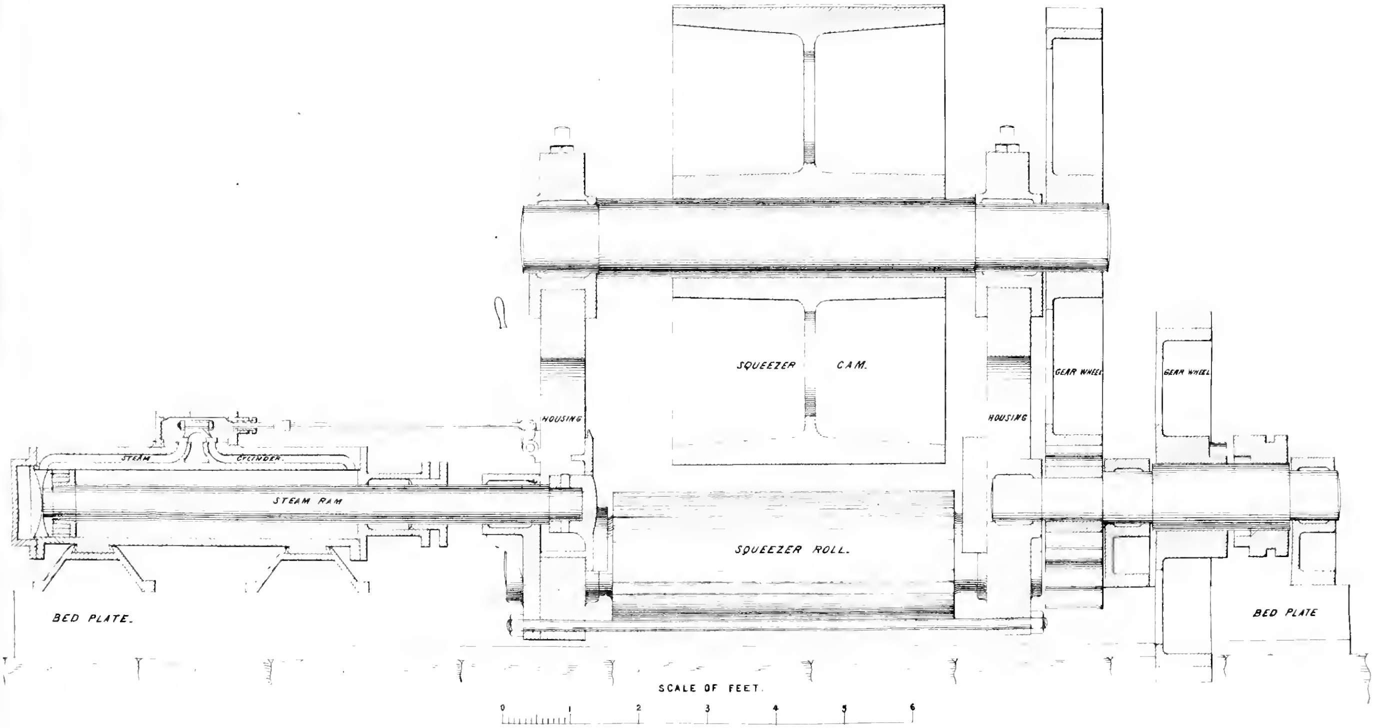


Nº 6.

DANKS'S ROTARY PUDDLING MACHINE.

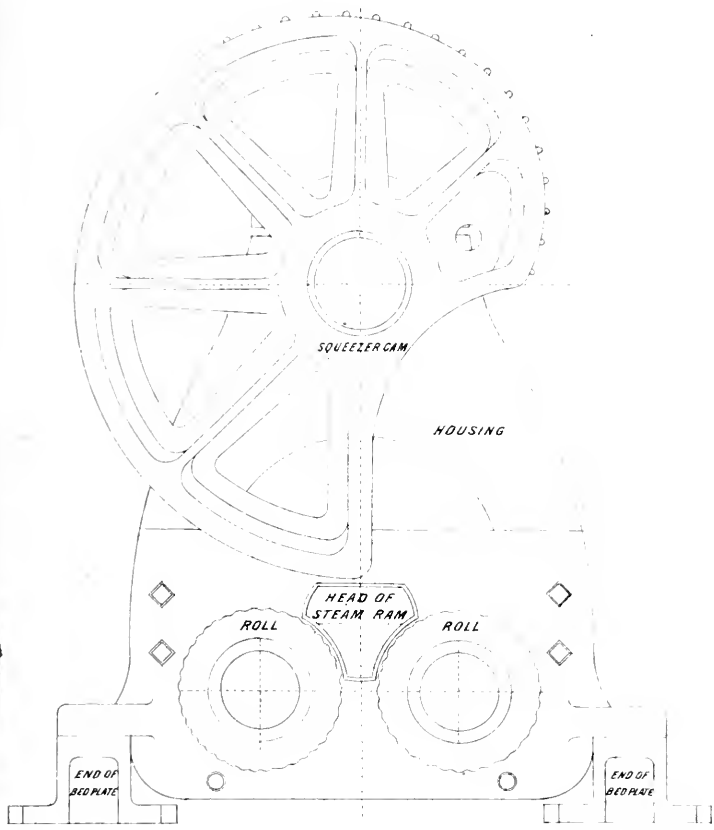
SQUEEZER,
FRONT SECTIONAL ELEVATION.



DANKS'S ROTARY PUDDLING MACHINE.

SQUEEZER END ELEVATION

No 7



SCALE.

1 2 3 4 Feet

PROCEEDINGS

OF THE

IRON AND STEEL INSTITUTE.

MEETING HELD AT GLASGOW, AUGUST 6TH, 1872.

PRESIDENT: MR. HENRY BESSEMER.

THE fourth provincial meeting was commenced at the Corporation Galleries, Sauchiehall Street, Glasgow, on August 6th, 1872.

The following is a list of articles exhibited:—

A series of samples of coal and ironstone minerals in the Lanarkshire district, by Mr. Ferrie, of the Monkland Iron and Steel Company.

Specimens of Scottish carboniferous sandstones, cannel coal, &c.

Model of a Reversing Rolling Mill, illustrating Mr. Stevenson's system of reversing gear.

Specimens of engineers' and joiners' tools, by Messrs. Matheson and Sons, of Glasgow.

Model of the result of a boiler explosion, by Mr. Edward Bindon Marten, Stourbridge, chief engineer of the Midland Steam Boiler and Inspection Association.

Asbestos packing for steam engines, by the Patent Asbestos Company.

Specimens of iron, by the Glasgow Iron Company.

Model of a patent waterbottom refinery, by the same Firm.

Case of forged iron screws, by Messrs. H. P. Boyd & Co. (Limited), Low Walker, Newcastle-upon-Tyne.

Specimens of cast and finished steel made by Attwood's process, by Mr. Charles Attwood, Wolsingham, Durham.

Specimens of stone from Messrs. G. & R. Nixon's Fire-Stone Works at Bellingham, Northumberland.

Non-conducting composition for covering steam boilers, by Mr. Fleming, Glasgow.

Steel top-rail dovetailed to iron, by Messrs. W. Thomson, Railway Foundry, Normanton.

A number of ornamental specimens of cast-iron (gilt, silvered, bronzed, and coloured), by Messrs. Smith & Sons, Glasgow.

Models of a hydraulic hoist for blast furnaces, and also a blast furnace bell patented by the firm, by Messrs. Head, Wrightson and Co., Teesdale Iron Works, Stockton-on-Tees.

Model and section of Whitwell's patent hot-blast fire-brick stove for blast furnaces, by Mr. Thomas Whitwell, Thornaby Iron Works, Stockton-on-Tees.

Specimen of a mass of iron rent by an explosion of dynamite.

A clock and a "heartsease" balance-wheel and self-registering barometer, by Messrs. Muirhead & Sons, Glasgow.

Models of vessels, by Messrs. R. Napier & Sons, Govan.

Do. by Messrs. Jno. Elder & Co., Fairfield, Govan.

Do. by Messrs. A. & J. Inglis, Pointhouse, Govan.

Electric bells for ships, by Messrs. D. & G. Graham.

Pressure-Log for measuring the speed of ships, by Mr. James R. Napier, Glasgow.

Ships' lamps, by Mr. William Harvey.

Model of Brown's patent paddle floats.

Allen's patent engine governor, by Messrs. Whitley, Partners, Leeds.

Designs for double houses in blocks for workmen and colliers, by Mr. J. P. Harper, Derby.

Model of Thomas's patent melting furnace, by Messrs. W. Bacon and Co., Acklam Refinery, Middlesbrough.

Section of Root's patent boiler.

Model of Gall's patent smoke prevention apparatus, by Mr. A. Fleming, Glasgow.

Two large blocks of Scotch splint coal from the pits of the Glasgow Iron Company.

Coil of wire manufactured by Messrs. Richard Johnson and Nephew, 27, Dale Street, Manchester.

Model of new form of revolving puddling furnace, by Mr. A. Spencer, West Hartlepool.

Model of Dornoy's revolving rabble, as applied to an ordinary puddling furnace, by Mr. F. A. Paget, C.E., London.

Case illustrating Zore's sections of channel and other iron.

The following works were open to the inspection of the members during the time of their visit:—Wm. Baird & Co., Gartsherrie; Coltness Iron Co., Coltness; Neilson & Co., Summerlee; Robert Addie, Langloan; Merry & Cuninghame, Carnbroe; Shotts Iron Co., Shotts; Monkland Iron Co., Calderbank; Hannay & Sons, Blochairn; Glasgow Iron Co., St. Rollox; Rochsolloch Iron Co., Rochsolloch; Gray & Wylie, Clifton; Thomas Jackson, Coats Iron Works; John Williams & Co., Wishaw; Henderson & Dimmack, Drumpeller; Thomas Ellis, North British Iron Works; John Spencer, Phœnix Iron Works; Coatbridge Tin-plate Co., Coatbridge; Mossend Iron Co., Mossend; Clydesdale Iron Co., (Limited), Clydesdale; David Colville, Motherwell; Barclay, Curle, & Co., Shipbuilders; T. Wingate & Co., Shipbuilders, Whiteinch; R. Napier & Sons, Shipbuilders, Anderston and Govan; London and Glasgow Engineering Co., Shipbuilders, Govan and Anderston; J. Elder & Co., Shipbuilders, Govan; J. & G. Thompson, Finnieston Street, Anderston; W. & A. M'Onie, Engineers, West Street, Tradeston; Mirrlees, Tait, & Watson, Engineers, West Street, Tradeston; Neilson & Co., Engineers, Springburn; North British Locomotive Works, Cowlairs; Dübs & Co., Engine Works, Little Govan; Laidlaw & Son, Founders, Mile-end, &c.; Edington & Sons, Phœnix Foundry, Glasgow; Walter Macfarlane, Saracen Foundry; George Smith & Co., Sun Foundry; Caledonian Locomotive Works, St. Rollox; Alexander Stephens & Co., Govan; A. & J. Inglis, Shipbuilders, Partick and Warroch Street, Glasgow; Finnieston Steamship Co., 30, Lancefield Quay, Glasgow.

The President, in opening the proceedings of the meeting, said it was with great pleasure that he again found himself face to face with the members of the Institute, especially so having regard to the favourable circumstances, and the happy auspices, under which they met. In most of their former meetings, it had been more or less difficult to accommodate the numerous and still-growing numbers of members joining the Institute. Fortunately, however, they had that day the advantages presented by the spacious and convenient rooms of the Corporation Galleries; more convenient rooms than those it would be scarcely possible for them to have, and he was sure that all the members would be gratified when he told them that they were indebted to his friend on his right (the Lord

Provost of Glasgow) for the facilities and comfort which they thus enjoyed, he, in connection with his colleagues, having kindly placed the rooms at the disposal of the Institute.

The Lord Provost was quite sure that he not only expressed the feelings of himself and the officials, but of everyone who had anything to do with the management of the city, when he said how happy they were to meet such a large, influential, and he was sure, in many cases, so many talented individuals in the city of Glasgow. They were always glad to meet with eminent men when they came to visit them, but they were, on this occasion, especially glad to meet the members of the Iron and Steel Institute, because they were connected with a trade upon which the inhabitants of Glasgow very much depended. They were aware that Glasgow was the centre of the Scotch iron trade, and there they depended very much upon it he believed, particularly with regard to iron shipbuilding, and their city was now about as important, in that respect, as any city in the kingdom. Most of the gentlemen present were probably aware of the extent of their out-turn during the last year, amounting to not less than 1,115,000 tons in the department of iron shipbuilding on the Clyde. He sincerely trusted that the members of the Institute would have a pleasant and an agreeable meeting; he was sure that whatever could be done on their part to facilitate the views of the members, or to accommodate them in any way, they would be most happy to do. It afforded him the very greatest pleasure to place the rooms at their disposal, and he sincerely trusted that they would not only have some pleasure and comfort in-doors, but that the weather would be such as to give them an opportunity of visiting some of the Highland lochs, for he was quite sure that the scenery in the neighbourhood of Glasgow was well worthy of their attention. Many visitors were arriving at Glasgow daily—and amongst them an immense number of Americans—still there was room, and he hoped they would find the business of visiting the various spots of interest a pleasant one. He wished them all a happy meeting. They had had a very good commencement down stairs in the shape of a good luncheon, and if they were as successful at the end as at the commencement of their gathering, it would be very satisfactory.

The President said that in the various centres of the iron manufacture, which it had been the good fortune of members of the

Institution to visit, they had discovered that each particular locality became famous for some special branch of the manufacture. The circumstances which led to that were various. In some cases the demands of the particular part of the country they visited helped in an especial manner to give a feature to the trade, in others the nature of the minerals and the nature of the fuel also governed it to a considerable extent. He need not tell the gentlemen before him that Scotland was known all over the world for its pig iron; wherever civilization had advanced, Scotch pig had formed its way—and a very valuable material it was to founders. Not only was it a useful material to manufacturers abroad, when exported in its raw state to almost every part of the world, but in this country it had arrived at very considerable perfection, and fine castings made from it—the hollow work—were so well known to them, that he was sure he need not dilate upon the subject. Its value to them all was very considerable, and it was, he thought, universally admitted, that Scotland had not been behind other localities in any department in the manufacture of iron in this country—and to that country they owed some of the greatest improvements that had been introduced in the iron trade. The discovery, by Mushet, of the blackband in Scotland, had given an impetus to the trade, and had supplied a material so well adapted for fine castings, that no doubt that one circumstance alone led very considerably to the advancement of that particular branch of the trade which was principally carried on there, although in later times the manufacture of malleable iron had made considerable progress. Following upon that were many other steps, but passing over several, they came to one of so marked a character that it was impossible to pass over that part of the subject without some reference to it—he spoke of the introduction of the hot-blast by Mr. Neilson. What Scotland had gained by that invention, and indeed what the whole world had gained by it, it would be difficult to define; suffice it to say, that the invention was now universally recognised as a necessity in the iron manufacture in the country. He would not detain the members of the Institute by enlarging upon that subject, as it was one with which all present were thoroughly well acquainted, and about which many of them could read him a lesson. He would, therefore, conclude what he had to say in that respect

by commencing the business proceedings of the day, and would, therefore, call upon them to nominate scrutineers to examine the voting papers for the new members.

The business of the meeting was commenced by the appointment of Messrs. Jenkins and Snelus as scrutineers to examine the voting papers for the election of new members. These gentlemen subsequently reported that the following eighty had been duly elected :—

NAME.	ADDRESS.
Addie, James	Langloan Iron Works, Coatbridge, N.B.
Ainsworth, J. Stirling	The Flosh, Cleator, Whitehaven.
Armstrong, Joseph	G. W. Railway Works, Swindon.
Bagnall, Thomas, jun.	Warkton, Kettering.
Baird, James	Lonsdale Hem. Iron Co., Whitehaven.
Beardmore, William	Parkhead Iron Works, Glasgow.
Bishop, Frederick Sillery	The Mount, Stoke-upon-Trent.
Blau, Siegfreid	Burbach Iron Works, Saarbruck, Prussia.
Bolland, James	2, Great George Street, Westminster.
Briggs, Henry Currer	Glenhow, Saltburn-by-the-Sea.
Brockbank, William	Oxford Road, Manchester.
Brown, Richard	Shotts Iron Co., West Nile St., Glasgow.
Brunlees, James	5, Victoria Street, Westminster, S.W.
Bull, James	Cliff Vale Iron Works, Stoke-on-Trent.
Bull, Joseph	Cliff Vale Iron Works, Stoke-on-Trent.
Bullivant, W. M.	114, Fenchurch Street, London, E.C.
Butler, Edmund	Kirkstall Forge, Leeds.
Byers, J. S.	Stockton.
Cadell, Henry	Bridgeness Iron Works, Bo'ness, N.B.
Carlton, James	Norbury Booths, Nutsford, Cheshire.
Cassels, Jno. R.	Glasgow Iron Works, Glasgow.
Chapman, Henry	11, Rue Louis-le-Grand, Paris.
Cheesman, Wm. T.	Hartlepool.
Colquhoun, Major James	Seaton Carew, West Hartlepool.
Danks, Samuel	525, East Third Street, Cincinnati, Ohio, U.S.A., & Royal Exchange, Middlesbro'.
Day, St. John Vincent	166, Buchanan Street, Glasgow.
Dodds, Matthew B.	Stockton.
Dunlop, James	Clyde Iron Works, Glasgow.
Elliott, John H.	Hive Iron Works, Jarrow-on-Tyne.
Evans, Frank H.	London.
Faviell, Henry F.	Atlas Works, Sheffield.
Forester, W. H.	Sketty Park, Swansea.
Gillott, Thomas	Farnley, near Leeds.
Gilmour, Allan	Woodend, Kilmarnock, N.B.
Griswold, Chester	Troy, New York, U.S.A.
Hall, William Fairbairn	Haswell Colliery, Durham.
Hannay, John	43, West Regent Street, Glasgow.
Hannay, Thomas	43, West Regent Street, Glasgow.
Healey, B. D.	Swansea.
Heath, Robert, jun.	Biddulph Iron Works, Stoke-on-Trent.
Howard, James	Bedford.
Hutchings, E. J.	88, Portland Place, London, W.
Jackson, John	Clay Cross, Chesterfield.
James, Thomas	Redcar Iron Works, Redcar.
Jardine, George	Western Club, Glasgow.
Jenkins, James G.	Ditton Brook Iron Wks., near Warrington
Jones, Frederick F.	Newport Rolling Mills, Middlesbro'.
Kay, Jno. Z.	Phœnix Iron Works, Glasgow.

NAME.	ADDRESS.
Kislanski, W.	14, Rue des Eglises, Brussels.
Jaques, Robert	Middlesbrough.
Laidlaw, David	Glasgow.
Landale, Andrew	Lochgelly Iron Works, Fifeshire.
Mayer, J.	Bochum, Prussia.
McKenzie, John	Glasgow.
McKerrow, Alexander	5, Victoria Street, Westminster.
Morton, Henry T.	Biddick Hall, Fence Houses.
Napier, Robert D.	Hyde Park Street, Glasgow.
Neilson, W. Montgomery	Queenshill, Kirkcudbright.
Noble, Captain	Elswick Iron Works, Newcastle-on-Tyne.
Ormiston, J. W.	Shotts Iron Works, Glasgow.
Palmer, Jno. Brough	Jarrow-on-Tyne.
Pearson, W. G.	Park Works, Gateshead.
Potts, John Thorpe	Boston, Mass., U.S.A.
Richardson, John	Nantyglo & Blaina Iron Works.
Richardson, T. G.	Killamarsh Forge, Chesterfield.
Ross, Jno.	Loftus Iron Co., Middlesbro'.
Scattergood, J.	Stour Valley Wks., Spon Lane, Brm'gham
Stevenson, Graham	Airdrie, N.B.
Sumner, William	Brazenose Street, Manchester.
Taylor, John...	Earsdon, Northumberland.
Tolmie, Alexander	Newton Burn, Innellan, near Greenock.
Toogood, Henry	16, Parliament Street, Westminster.
Wallace, David	Gartsherrie Iron Wks., Coatbridge, N.B.
Weir, William	Gartsherrie Iron Wks., Coatbridge, N.B.
Wendel, Henri de	Hayange, Lorraine, France.
Wendel, Robert de	Hayange, Lorraine, France.
Williams, Jno.	The Green, Wishaw, N.B.
Willis, W. C.	Loftus Iron Co., Middlesbro'.
Wrightson, Thomas	Teesdale Iron Works, Stockton.
Young, John	Phœnix Iron Works, Glasgow.

The President moved that the report of the scrutineers be received and adopted. The motion having been seconded by Sir J. G. N. Alleyne, was unanimously agreed to.

The General Secretary read the following recommendations of the Council:—

"The Council hereby present the following as the list of the members that retire, in accordance with the rules, at the next annual meeting:—

Vice-Presidents.—Mr. W. Menelaus, Mr. Jos. T. Smith, and Mr. Walter Williams.

Members of Council.—Mr. W. S. Roden, Mr. C. W. Siemens, Sir J. Whitworth, Mr. Edward Williams, and Mr. George Wilson.

"The Council have also considered the propriety of recommending to this meeting the name of a gentleman to serve as President for the two years commencing at the next annual meeting. They have unanimously agreed to nominate Mr. I. Lowthain Bell as President-Elect, and they trust that this selection will meet the approval of the members.

"The nomination of Mr. Bell will leave a vacancy in the list of Vice-Presidents, and the Council recommend that Mr. Edward Williams be nominated to fill this vacancy.

"The Council recommend that the following members should be elected to fill the vacancies caused by retirement :—

VICE-PRESIDENTS.—Mr. W. Menelaus, Mr. Jos. T. Smith, and Mr. Walter Williams.

MEMBERS OF COUNCIL.—Mr. W. S. Roden, Mr. C. W. Siemens, Mr. Henry Sharpe, Mr. Walter Neilson, and Mr. James Hunter."

Mr. Forbes (Foreign Secretary), read the list of names of the foreign visitors.

This business being completed, the following paper was then read :—

ON THE GEOLOGICAL POSITION AND FEATURES OF THE COAL- AND IRONSTONE-BEARING STRATA OF THE WEST OF SCOTLAND.

BY MR. JAMES GEIKIE, F.R.S.E., EDINBURGH.

THE geologist, or mining engineer, who has confined his examination of British carboniferous strata to the coalfields of England, would be apt, upon a sudden introduction to the West of Scotland, to make some mistake as to the geological position of the Scottish carboniferous deposits. In such districts as Paisley, Carluke, Wilsontown, Auchinheath, or Dalry, he would see numerous coal and ironstone pits, and might probably conclude that he had there the equivalents of the English coal measures. Nor is it at all unlikely that he might even for a time feel inclined to class the "oil-shale group" of Linlithgowshire under the same great division. But a little investigation would soon convince him that the appearances which had at first impressed him were altogether misleading, for he would find the coal seams in many of the Scottish districts interstratified with beds of limestone, the fossils in which belong to similar genera and species as the organic remains so abundantly met with in the carboniferous limestone of England. And, if he continued his investigations, he would ere long come to the conclusion, that the conditions under which the Scottish carboniferous strata were amassed, departed greatly from those that seem to have been characteristic of the English area. It has appeared to me, therefore, that a slight sketch of the more characteristic features of

the Scottish coal-bearing strata might not be unacceptable to those whose observations may have been limited to the area of the English coalfields.

A glance at any geological map of Scotland will show that the Carboniferous Formation is for the most part restricted to that broad belt of undulating low ground that extends from sea to sea, between the northern highlands on the one hand, and the southern uplands on the other. Throughout this area the strata are arranged in a series of great basins with intervening ridges. The chief basins, beginning in the east, being first, the basins of Fifeshire and Midlothian; second, the Lanarkshire and Stirlingshire basin; third, the broken and interrupted basins of Ayrshire and the south. The description of any one of these basins would in large measure serve for the others, for throughout the whole carboniferous area the same type of structure prevails. And, therefore, although the brief sketch I offer will refer chiefly to the basins of the west, yet it may be taken as a fair presentment of the Scottish carboniferous system.

We find that this system is capable of being divided into four great series, which, beginning at the top, are as follows:—

1st. The Coal Measures.
2nd. The Millstone Grit.
3rd. The Carboniferous Limestone.
4th. The Calciferous Sandstone series.

It is obviously impossible that, in the limited time at our disposal, I can treat of all these series in detail. I shall, therefore, pass lightly over those which do not differ markedly from the equivalent strata in England, and shall dwell chiefly upon such appearances as to an English geologist would seem abnormal.

Beginning our investigations with the lowest series, we find that the basement beds of the Carboniferous Formation, as developed in Scotland, consist of two well-marked groups, which, with some interruptions, are found to be more or less continuous throughout all our carboniferous areas.

The lower group is composed for the most part of sandstones, with occasional grits and conglomerates, and the beds are usually separated by intervening layers of soft sandy shales and marly clays. Towards the base of the group, there also occur here and there irregular bands of a coarse concretionary limestone or corn-

stone. Bands of the same calcareous rock may also be occasionally met with in the middle and upper portions of the group, but they certainly get most abundant towards the lower horizons.

In some districts the strata are white, grey, and yellow, but their most usual colour is some shade of red. Wherever the base of the system has been found, the red sandstone group appears to rest unconformably upon some of the older palæozoic formations. In some places, however, they pass down quite conformably into strata which have usually been classed as Upper Old Red Sandstone, but which ought rather to be considered as the basement beds of the carboniferous system.

With the exception of the cornstones (which are often quarried in the outlying pastoral and agricultural districts), the red sandstone yields no minerals of economic importance. The sandstones themselves are usually coarse-grained and soft, and not well adapted for building purposes; although, here and there harder beds are sometimes come upon.

The overlying strata, which compose the upper group of the Calciferous Sandstone series, present many features of interest and importance. Unlike the lower group (which has a great sameness of character throughout the country), this upper group is exceedingly variable, in some districts abounding in minerals of great commercial value, in other regions yielding nothing of economic importance, and even occasionally disappearing altogether.

In the districts which lie along the eastern borders of the Lanarkshire basin (Linlithgowshire), it consists of a vast series of thick massive sandstones, with intervening strata of argillaceous shales and marls. Among these are intercalated occasional seams of coal, limestone, and bituminous shales, which last, indeed, give its chief value to this group.

The coal seams are few in number; the chief seam (that of Houston) reaching a thickness of six feet. The oil shales again are of variable thickness, and range from one or two feet to seven or eight feet. There are five principal beds, with a united thickness of about fifteen or sixteen feet, but the seams vary considerably over a comparatively limited area. Still more variable are the limestones, that of Queensferry or Burdiehouse, which has an average thickness of nine feet, occasionally swelling out to forty or even to seventy feet.

The sandstones are well known, and have been most extensively quarried, most of the principal edifices in the Scottish lowlands having been built of freestones belonging to this group. The stone is usually fine grained, and not readily acted upon by the weather, as may be well seen in some of the older buildings, upon which the fine carving and chiselling are, in many cases, almost as perfect as when the work came from the hands of the masons.

Such is the general character of this group as developed in Linlithgowshire along the eastern borders of the Lanarkshire coal-field. When the same strata are followed westward along the southern outskirts of this basin, they are found to undergo certain great changes, which almost entirely obliterate the leading features of the series as represented in the typical localities of the Lothians.

It will, bye and bye, come to be a question of some importance whether we may expect to find in Lanarkshire those oil shales, the discovery of which has given rise to a new industry, and introduced to hitherto quiet rural and pastoral districts the dust and din of town. After a careful and somewhat laborious examination of the evidence, however, I am sorry to say that there appears to be little or no hope that the upper calciferous group in the West of Scotland will ever yield those oil-bearing or bituminous shales for which the same group, as developed in Linlithgowshire, is so remarkable. My reasons for this opinion may be briefly stated :—

I have just described the Calciferous Sandstone series as being composed of a lower group of red sandstones, and an upper group in which the presence of bituminous shales is a salient feature. Now, I find that, when the oil-shale group is traced westwards from Linlithgowshire along the borders of the Carboniferous area, it gradually thins away to such an extent that shortly after entering Lanarkshire it disappears altogether, until (in the district of Carluke) we get the basement beds of the carboniferous limestone resting directly upon the lower red sandstone group. Proceeding still further westward, we at length reach a great succession of volcanic rocks immediately underlying the limestone series. These volcanic beds occupy all the high ground that stretches from Strathavon along the borders of Lanarkshire, Ayrshire, and Renfrewshire. They form the hills seen to the south of Glasgow, and all the rocky ground above Paisley, whence they continue onwards to the Firth of Clyde at Bowling. On the opposite side of the Clyde

basin, the Kilbarchan and Campsie Hills are a continuation of the same series of volcanic rocks, which thus form a kind of rude horse-shoe-shaped rampart enclosing the western outskirts of the great Lanarkshire basin.

Now, it has been ascertained that this vast mass of volcanic material is beyond all doubt the equivalent of the Calciferous Sand-stone series—that is to say, that while the red sandstones and upper oil-shale group were accumulating in the east, these volcanic beds were being gradually piled up in the west—that in short they occupy the position which otherwise might have been filled by aqueous deposits.

In the south of Ayrshire the volcanic beds disappear, and their place is taken by two distinct groups of strata—a lower set of red sandstones, and an upper group of blue shales, clays, and cement-stones, which show no trace either of coal or bituminous shales.

It is hardly necessary to go more minutely into this matter here, but from what I have advanced, it must be apparent that in the area of the Lanarkshire basin—between the Kilbarchan Hills on the one hand, and the Hills of Eaglesham and Paisley on the other —it is hopeless to anticipate that the oil-shale series will ever be discovered. Throughout this area, the beds immediately under-lying the Carboniferous Limestone series consist, doubtless, of hard whinstones and tough volcanic ashes; while the general aspect of the Calciferous Sandstone series, as developed in Ayrshire, is such as to hold out little expectation of better fortune in the search for oil-shales in that district.

Before passing from this part of my subject, I may be allowed to indicate briefly the character of those physical conditions which would appear to have marked central Scotland during the deposi-tion of the Calciferous Sandstone series. This may perhaps serve to bring more vividly before the mind of those who have no special knowledge of localities, the general succession and varying characteristics of the series. When the lower group of Red Sand-stones began to be deposited, the regions of the highlands and the pastoral uplands of the southern counties formed, at that distant period, dry land; while a broad belt of water stretched between the northern and southern hilly districts, and covered over what is now the great Central Valley of Scotland, or the broad straths of Forth and Clyde. This may be inferred from the fact that

where the lower beds of the red sandstone group abut upon those older formations which form the boundaries of the carboniferous strata, they almost invariably become coarse-grained, and often highly conglomeratic—and the pebbles and stones of which these conglomerates are composed are clearly derived from rocks of Old Red Sandstone or Silurian age. In short, we have no difficulty in coming to the conclusion that the basement beds of the carboniferous system have been built up out of the ruins of those older formations, which at the dawn of the carboniferous epoch, formed lines of coast that undulated obliquely from south-west to north-east, along the flanks of what are now the highlands and southern uplands. While such conglomerates were accumulating as gravel and shingle banks along these primeval shores, finer grained sand was being laid down in deeper water at a greater distance from the land. From the general coarseness of the red sandstones, and from the frequent occurrence of ripple-marks, and the abundance of diagonal or false-bedding, so characteristic of the group, it may be concluded that the sea or estuary in which the beds began to be deposited was of no great depth, for the sediment was apparently liable to be continually shifted about by changing current action. The occasional presence of a drifted plant or tree in a good state of preservation shows, moreover, that the land could not have been far distant,—a conclusion which is still further supported by the fact that the tracks of sea-worms and crustaceans may sometimes be traced upon the surfaces of the finer grained beds.

Be this, however, as it may, it is certain that the deposition of the red sandstone group commenced and was carried on during a period of subsidence. The Scottish area at this time was slowly sinking down, so that eventually the sea stretched far into the heart of the southern uplands, and sand came to be laid down in regions which, at the commencement of the carboniferous epoch, were in the condition of dry land.

After vast heaps of sand had been deposited over the submerged tracts, the volcanic forces began to show some activity, and several submarine eruptions took place. One volcano broke out upon the sea bottom at Edinburgh, and after throwing out showers of stones and sheets of lava, became again quiescent. In Haddingtonshire and Fifeshire, however, the igneous forces continued in activity throughout nearly the whole period. But it was in the western

districts, where the fire forces extruded upon the floor of the sea the most extensive accumulations of volcanic material. Numbers of submarine volcanoes opened upon the sea bottom in what are now the shires of Stirling, Dumbarton, Lanark, Renfrew, and Ayr, and from these foci sheet after sheet of molten rock was ejected, covering up those beds of red sand which paved the floor of the sea.

Between Edinburgh in the east, and Lanark in the west, however, there was a comparatively quiet area where the usual sediment was allowed to collect. But so long a time had now elapsed from the beginning of the carboniferous epoch that the sea bottom had become well-nigh silted up. This may have been due to a cessation of the movement of subsidence, or that movement may have been converted into one of elevation; or, again, the deposition of sediment may have taken place at a rate which masked or concealed the downward movement. The shallowing of the sea may have been brought about by any of these causes; all we know for certain is that it did become shallow, and instead of a broad open belt of water extending across the central part of what is now Scotland, there appeared a wide stretch of low, flat country, intersected with numerous ramifying creeks, and straggling brackish-water lakes and lagoons. Tree-ferns and other plants of tropical and subtropical aspect clothed the flat country with a luxuriant growth, while the creeks and lakes slowly silted up with fine mud and decaying vegetable matter. In some of the deeper pools gathered a calcareous silt, in which were gradually entombed the remains of numerous fishes, belonging to wholly extinct species, but some of which were allied to the sharks of southern seas, and to the bony-scaled lepidosteus of the Nile. Here and there stones and dust were showered forth by solitary little volcanoes, the small outposts of those larger eruptions, which had so filled up the bed of the sea in the western districts that in the later stages of their activity they became subaerial. And thus from the hills of Campsie and Kilbarchan south to the high grounds near Kilmarnock, and from Strathavon west to Ardrossan, was one wide Phlegræan field. In Haddingtonshire and Fifeshire also, there existed at this time a series of large and active volcanoes.

While such continued to be the condition in the west and east of Scotland, a process of depression seems again to have set in, and the mud-flats of Linlithgow and the central districts disappeared below

the sea. During this subsidence, great accumulations of fine sand gathered over the site of the forests, mud-shoals, creeks, and lagoons. Once more, however, the sea became silted up; sluggish muddy rivers meandered over the re-elevated bed of the sea; tree-ferns again clustered upon the slimy flats; vegetable and calcareous silts thickened in the creeks and lagoons, and the former conditions prevailed, only to be interrupted, however, by subsequent movements of depression, during which fresh accumulations of sandy sediment were poured over the surface of the drowned forests and lagoons.

Such would appear to have been the physical conditions under which the oil-shale group of Linlithgowshire was deposited. Tree-ferns and their dense undergrowth gave rise to coal seams; the calcareous and vegetable silts of the creeks, lakes, and lagoons to limestone and bituminous shale. Again, the massive beds of freestone mark out those intervening periods of depression during which the mud-flats and lagoons gave place to comparatively open water.

In fine, then, we become aware that the accumulation of the bituminous shales, and their associated strata, was restricted to a comparatively limited area in the great Central Valley. To the east and west of this area, thick masses of volcanic material are intercalated with, and overlie, the lower red sandstone, and occupy the position of the upper or oil-shale group; and beyond the volcanic hills in Ayrshire, where the upper group again puts in an appearance, there are no hopeful indications of the possible existence of either bituminous shales or coals.

The carboniferous deposits, just described, are poorly developed in England. In South Wales, a thickness of some 200 feet of "dark earthy shales, interstratified with yellow sandstones, and always with thin flaggy limestones in its upper part," appears to be the equivalent of the Scottish Calciferous Sandstone series. In the Midland districts there are no representatives of the series in question, while in the North the true base of the carboniferous system is concealed.

CARBONIFEROUS LIMESTONE SERIES.

I come now to consider the next great series of strata—namely, the Carboniferous Limestone. This series consists of three well-marked groups:—

1st. An upper group, chiefly of sandstones, &c., with three or more seams of limestone.

2nd. A middle group of sandstones and argillaceous shales, with numerous seams of coal and ironstone, but no limestone; and

3rd. A lower group of strata, with seams of coal and ironstone, and a variable number of limestones.

These groups I shall describe briefly in ascending order.

The lower group is exceedingly variable, both as regards the number and quality of its coal, ironstone, and limestone seams, and the absolute thickness of the strata in which these occur. In some of the Ayrshire basins, for example, we find only one or two limestones in a thickness of eight or ten fathoms of strata, and not unfrequently no workable seams of coal or ironstone. In other districts, as at Carluke, and along the southern borders of the Lanarkshire coalfield, no fewer than eleven limestones occur in a thickness of fifty-five fathoms of strata, while, at the same time, we have a number of excellent bands of clay ironstone.

The thickness of the limestone beds themselves is as variable as that of the strata in which they are inserted. In the district of Carluke, for example (where the limestone series has a typical development), we find, as already remarked, eleven separate seams, besides two or three small lenticular seams, of restricted or local range. Of the more persistent beds, only four reach a greater thickness than 3 feet—the "Main" or chief limestone attaining an average of only 4 feet 6 inches. One or two of the other limestones, however, thicken out here and there to 7 and 9 feet. Only two of the limestones in this lower group at Carluke, however, are wrought to profit—the others being too often highly argillaceous and impure.

It is worthy of note that three or four of the limestones rest upon a pavement of coal, the coal underneath the Main seam of Carluke being sometimes thick enough to suffice for burning the stone.

The most persistent of all the limestones of this lower group is the Main seam of Carluke, which, under various names, occurs throughout all the coalfields of the west of Scotland, Another somewhat persistent seam is that known as Hosie's limestone, which lies from 18 to 20 fathoms above the Main seam. These two limestones, as we shall presently see, mark a most important horizon.

Of the coals belonging to this lower group not much need be said. The most constant seam is that already referred to as underlying the Main or Hurlet limestone. This coal varies from a few inches in some places to 3 ft., or 5 ft. 6 in. in other localities. In one or two districts, moreover, a coal accompanied by an oil-shale is met with a few fathoms below the Hosie limestone.

The ironstones belonging to this group are often of excellent quality. They consist principally of clay bands, varying in thickness from several inches to 1 ft. and more; and they are often so closely aggregated that several seams are taken out in one working.

Clayband ironstones occur occasionally between the Hosie and Hurlet limestones, but they are best developed in the strata that immediately overlie the former. In this position also there occur in some localities one or two seams of blackband ironstone, which reach a thickness of 1 ft. or 1 ft. 6 in.

Such is the general character of the lower limestone group of Lanarkshire and the west of Scotland. In the coalfields of Ayrshire, however, the limestones frequently thicken out so as greatly to surpass in importance the equivalent seams of Lanarkshire—the Main limestone of Carluke being represented by the Hawthorn limestone of Muirkirk, which is 18 ft. 6 in. thick, and by the Beith limestone of Dalry, which ranges from 60 ft. to 100 ft. in thickness.

The middle group of the limestone series is characterised by the presence of numerous coal and ironstone seams, and by the total absence of limestones. One or two blackband ironstones also belong to this horizon. About midway between the top and bottom of the series occurs the well-known gas coal of Lesmahagow, and in or about the same position gas coals are met with in several other localities. The common coals belonging to the middle group of Lanarkshire rarely exceed 2 ft. 6 in. or 3 ft. in thickness. But in Ayrshire the same group shows a number of thick seams, two of which reach respectively 7 feet and 11 feet. Occasionally, also, the coal seams of this group have a tendency to come together so as to produce a locally thick bed. Such is the case at Edgehill, near New Cumnock, where four or five coals unite to form a seam 40 feet thick.

The upper limestone group of Lanarkshire has a great sameness of character in all the localities where it occurs. It generally contains three limestones, and here and there one or two lenticular

and inconstant seams of the same "mineral." The limestones are of variable quality and thickness. The highest and most important bed is known in different localities as the Arden, Garnkirk, Robroyston or Gair limestone. Sometimes it does not exceed three or four feet, but at Arden it is as much as 11 feet thick. Although this seam has been extensively worked in various localities it is not a limestone of the best quality, but often contains a considerable admixture of argillaceous matter. The under seams vary from 15 in. to 3 or 4 ft. At Calderwood, however, the lower limestone of this upper group is accompanied by a cement-stone which is held in some estimation. In the Muirkirk coalfield, the upper limestone group shows six seams of limestone with a united thickness of 67 or 68 ft.

The strata in which the upper group of limestones occurs consist for the most part of sandstone, with here and there thin unworkable seams of coal. But in the Muirkirk field, where the whole limestone series is abnormally developed, two good coal seams are met with in this upper group, which reach 3 ft. 6 in. and 8 ft. respectively.

No volcanic rocks of contemporaneous origin occur in the Carboniferous Limestone series of Lanarkshire, although rocks of this character are so extensively developed in the same series in Linlithgowshire. In the north of Ayrshire, a belt of volcanic rocks forms the division between the Carboniferous Limestone and the overlying Millstone Grit and Coal Measures.

The constant alternation of coal seams with bands of limestone and beds of sandstone, so characteristic of the Scottish limestone series, plainly shows that the strata were accumulated during a prevailing movement of subsidence. But this movement may have been interrupted by long pauses, or even by occasional movements in the opposite direction.

The prevalence of thick limestones in the lower group, indicates that in the earlier periods deep sea conditions were the rule in central Scotland. But these conditions were now and again interrupted, and wide stretches of flat ground covered with a dense growth of vegetation occupied the site of the old sea. We have also abundant evidence of the former presence of estuaries, and brackish or fresh water lakes and lagoons.

As it is in the middle group of the limestone series where the coals and ironstones are most abundantly developed, and where lime-

stones never occur, we may reasonably infer that during the deposition of this group the prevailing physical conditions characteristic of central Scotland were those which appeared only at fitful intervals during the accumulation of the lower limestone group. The numerous coal seams point to the frequent recurrence of a land surface, and the gas coals and ironstones to the former existence of numerous wide lakes and lagoons. It is not uncommon to find lines and ribs of gas coal associated with our splint coals, and even with some common coals. Gas coals, indeed, are not unfrequently found to pass into common coals, or into black shales, and sometimes into blackband ironstones. And this arises from the mode in which these seams were accumulated.

Gas coal has certainly been deposited in water; it contains fresh water or brackish water fossils, and may be traced, as just stated, until it is found to pass into a black argillaceous shale. If we conceive of a more or less wide expanse of fresh water, surrounded by broad stretches of densely wooded flat grounds, we shall have the conditions under which the common coals, gas coals, and ironstones of the limestone series were most probably formed. Over the bed of the lake would gather a slimy vegetable mud, which, in some places, might be highly impregnated with ferruginous matter. Here and there this slime or black vegetable mud would pass into a dark clay or silt at points where streams entered the lake; while all along the shores, wherever the water shallowed, luxuriant growths of marsh plants would cluster upon the muddy bottom. Beyond this thick marshy growth, again, there would be the drier land, covered with enormous trees and a dense undergrowth of ferns. The plants that grew upon the land would give rise to common coal; the marshy vegetation to splint coal, and the dark vegetable silt to gas coal, oil-shale, and blackband ironstone; and all these seams would anastomose or pass into each other at certain points. And thus the same mineral seam may be alternately a common, splint, or gas coal, an oil-shale, or a blackband ironstone, according as the physical conditions varied at the time of its formation.

With regard to clay ironstones, I think they are often due to subsequent changes in the strata,—the carbonate of iron having been originally more or less diffused through the silt beds or shales, has segregated in time, so as to form irregular balls and bands.

But the extreme regularity of many of the bands would lead one to infer that these at least were due rather to deposition than to segregation.

During the formation of the upper limestone group, the prevalent conditions seem to have been marine. But occasional land surfaces made their appearance, and associated with these were the usual brackish and fresh water lakes and lagoons.

At the commencement of the limestone period in Scotland, the volcanic forces showed considerable activity along the eastern borders of the Lanarkshire basin, that is to say, in the western districts of Linlithgowshire. The great volcanoes (from which, as we have seen, the old lavas and tuffs of the Paisley and Kilbarchan Hills were ejected), had died out, or nearly so, before the basement beds of the limestone series began to be laid down. But the igneous forces in the area of Linlithgowshire still continued to pour forth melted matter even after the limestone period had commenced; for we find that at Bathgate, thick masses of basalt rocks are interstratified with the limestones, in such a way as to show that the igneous rocks are not intrusive but contemporaneous.

In other regions, as in the Fifeshire area, a few sporadic vents threw out showers of stones and comminuted matter upon the sea bottom; while in Ayrshire the deposition of the upper limestone group was brought to a close by an eruption of lava and tuff, which may still be traced across the country between Kilmarnock and Dalry.

In Lanarkshire itself, we find no evidence of the existence of volcanoes during the limestone period.

In many respects, the Scottish carboniferous series is, for the English geologist especially, one of the most interesting groups of strata. No two sets of rocks indeed could present a greater contrast than the English and Scottish limestone series. Take, for example, the great limestone of the North Staffordshire coalfield, where it attains a thickness of more than 4,000 feet—nearly all pure limestone—and compare this vast bed with the limestone series as developed in Scotland, where only a few thin beds of limestone occur, interstratified, however, among strata which are often exceptionally rich in seams of coal and ironstone. There can be no doubt that the Scottish beds are the exact equivalents of the thick Mountain Limestone of the midland district of England;

and we explain the disagreement between the two series, by inferring that the great limestone of England accumulated in deep sea, at a time when land and shallow seas alternated in the Scottish area. In further proof of this, I need do no more than refer to the fact (well-known to most of us here) that the great limestone as it is traced north from the midland counties becomes more and more split up with beds of shale and sandstone, especially towards the top of the series, until, near Berwick-on-Tweed, the base of the series itself comes to contain beds of sandstone and shale, and seams of coal. All this points unmistakeably to a passage from a deep to a shallow sea bottom. And thus we see how it is that in the Scottish area we should have so many old land surfaces associated with our limestone series, while in the more typical districts of England, the equivalent strata are wholly of marine origin.

THE MILLSTONE GRIT.

The next series in ascending order is the Millstone Grit. Little however need be said about it here, as it does not differ very much from the equivalent deposits of the English carboniferous areas. It is of variable thickness, ranging from only a few feet to upwards of 400 feet. It consists of a series of sandstones and grits, usually soft, and sometimes almost incoherent, but occasionally hard enough to be quarried for rough building purposes. Here and there we find, interstratified with the sandstones, a local lenticular bed of limestone, not often more than a few feet in thickness; that of Levenseat and Castlecary being by far the most important seam. In other districts, as in the neighbourhood of Garnkirk, the series yields excellent fireclay, which is extensively worked. Clay ironstones of good quality are also occasionally met with,—the Curdly seam being the best known of these. This ironstone is of variable thickness and purity, and occurs in nodular masses.

The conditions prevailing in Central Scotland during the deposition of the Millstone Grit do not appear to have greatly differed from those of the preceding limestone series. But the general absence of coal seams probably indicates that most of the tract lying between the northern highlands and the southern uplands was under water—and that conditions partly estuarine and partly marine prevailed during this period.

THE COAL MEASURES.

The millstone grit in Scotland, as in England, serves to divide the limestone series from the overlying Coal Measures. In Lanarkshire, the Coal Measures consist of two groups. 1st, an upper group of red sandstones; and 2nd, a lower group of the usual white and grey sandstones, with dark argillaceous shales, coal seams, and ironstones.

As the geological phenomena presented by the Scottish Coal Measures are quite analogous to those of similar deposits elsewhere, it is not necessary to enter into structural details.

The upper group consists of a series of red sandstones, with intervening sandy marl and impure fireclays. It contains no workable seams of coal, and rests unconformably upon the coal-bearing strata. In the central and deeper portions of the Lanarkshire coalfield, it probably reaches a thickness of more than 700 feet.

The lower or coal-bearing group I estimate to be at most about 1,400 feet thick—thus giving a united thickness of 2,100 feet for the series. But like all the other members of the Scottish carboniferous system, this series thickens and thins in a somewhat irregular manner.

The lower group contains eighteen workable coal seams, but some of these are either not continuous throughout the whole coal-field, or in places are too thin or poor to be economically worked. Taking them at their best, they would give a united thickness of some 70 feet, or thereby; but in many places they do not average more than 40 feet, or less. The thickest seam is that known as the Ell coal of Wishaw. This seam has been got as much as 14 feet thick, but in the Wishaw district it does not average more than 6 or 7 feet. In some districts the same coal becomes split up into two or three separate seams, which are usually in an unworkable condition. Both blackband and clayband ironstones occur in the group, but several of the seams are now nearly exhausted. The blackbands vary much in thickness, but do not often exceed 18 inches. At Goodockhill, however, the Crofthead slaty band is said to have reached the thickness of 6 or 7 feet.

The best-known seams are the Palacecraig ironstone; the Airdrie or Quarter blackband; the Bellside blackband; the Calderbraes ironstone (which occupies the position of what in other districts is known as the Kiltongue coal); the Bowhousebog or Braco upper

ironstone; and the Goodockhill or Crofthead slaty band. Besides these, there are one or two others of inferior quality which have not been much worked.

Clay-bands of fair quality are worked in connection with some of the coals, as at Shotts and Armadale.

Several seams of shale are also extensively wrought, especially in the neighbourhood of Airdrie. Perhaps one of the best known (I had almost said notorious) seams in the Scottish Coal Measures is the Boghead gas coal, or as some prefer to call it, the Torbanehill Mineral. This seam (the cause of so much litigation) occupies a position at the base of the coal measures.

Before concluding this very brief and sketchy notice of the Coal Measures, I may add that the deeper portions of the field are comparatively little proved yet. The known fields of blackband ironstone are (as already remarked) gradually approaching exhaustion, but there is ground for hope that in the districts to be explored new fields may be discovered. There is certainly no geological reason against the probability of their occurrence; on the contrary, all analogy would lead one to quite the opposite conclusion.

The conditions under which the coal measures were deposited seem not to have differed greatly from those which characterized the accumulation of the middle coal and ironstone group of the limestone series. Land-surfaces alternated with fresh and brackish water conditions (and also perhaps with occasional inroads of the sea,) up to the close of the period. As far as I am aware, no active volcanoes then existed in Scotland.

IGNEOUS ROCKS; FAULTS.

I have delayed so long over the phenomena presented by the aqueous strata, that I have left no space for any account of the igneous rocks associated with the Scottish carboniferous system. The contemporaneous masses have already come in for some notice, but I have hitherto made no reference to those destructive intrusive masses which, unfortunately, are too well known in most of our coalfields. These, I may just say, belong to three different geological ages. The oldest are those extensive sheets or floats of basalt rocks which cut the strata in a horizontal direction, and often make sad havoc of the coal seams. To a later date belong certain circular pipes of a coarse volcanic agglomerate, which pierce the

strata vertically, and which I believe to be the filled-up vents of old volcanoes of Permian age. The youngest igneous rocks are those long vertical walls or dykes of basalt rock, which intersect the strata in a direction from west to east, or north-west to south-east. These dykes would appear to be of the same age as the extensive masses of igneous rock which form the Giant's Causeway and the Isle of Staffa.

The faults and dislocations by which our coalfields are traversed, vary in size from mere shifts of a few feet to vertical displacements of not less than 400 fathoms. They belong chiefly to two different sets —one of which strikes approximately east and west, and the other approximately north and south—the latter being cut by the former.

From this rapid review of the more characteristic features assumed by the Scottish carboniferous system, it becomes evident that the series which diverge most from those that are typical of the English area are the Calciferous Sandstones and the overlying Carboniferous Limestone series. In England, the strata that underlie the Coal Measures and Millstone Grit are composed almost exclusively of beds which have been amassed upon a sea bottom. In Scotland, on the other hand, we find the strata upon which the true Coal Measures and Millstone Grit repose, giving evidence of numerous interchanges of land, fresh or brackish water, and marine conditions. While at the same time we are assured that during the accumulation of these underlying strata the eruption of melted matter and lapilli hardly ever ceased in central Scotland.

The history of the two lower series forms indeed one of the most instructive chapters of geology, and in the unravelling of their details lies the key to the whole structure of our coalfields. I have, perhaps, dwelt too much upon purely geological features, but I wished to show that by working out the history of those physical changes which witnessed the deposition of the carboniferous strata, it is possible in many cases to arrive at certain more or less definite conclusions as to the occurrence or non-occurrence of valuable minerals in hitherto unproved fields. And I also hoped, that by briefly indicating the kind of conditions under which our mineral-bearing strata were accumulated, I might convey to those who are not conversant with the details of the Scottish carboniferous system a clearer idea of those general or broad features which distinguish it from that of England.

The President was sure that the members had listened with great interest to the very able paper that had just been read. When they imagined the amount of labour and study involved in producing the results conveyed in it, they would be able to appreciate the value and importance of a paper like that to which had just listened.

Mr. Woodhouse very much doubted whether any gentleman in that room would venture to question the exactness and skill which had been displayed by the gentleman who had read the paper, in treating upon the subject of the Scottish iron and coal-fields. He (the speaker) might remark that he not had very great experience in connection with that subject, nor did he profess to know much of it: but there was one particular part in Scotland that he did know intimately—that was the Kilmarnock district—and he could testify that very great care had been displayed by the author of the paper,—so much so, in fact, that a more accurate description of that portion of the geological field could not have been given. With reference to the paper itself, there was just one passage to which he would refer for a moment, where the author said, "The numerous coal seams point to the frequent recurrence of a land surface, and the gas coals and ironstones to the former existence of numerous wide lakes and lagoons. It is not uncommon to find lines and ribs of gas coal associated with our splint coals, and, even with some common coals. Gas coals, indeed, are not unfrequently found to pass into common coals or into black shales, and sometimes into blackband ironstones." Now, no one who had studied at all the principles of geology, could doubt for one moment that those remarks very fully described the way in which these seams of coal had been formed. The next thing he would refer to was that part of the paper in which the author described the difference in the formation of the carboniferous series in the Midland Counties and that of Scotland. He himself had entertained very great doubts, and many questions had arisen in his mind as to the stratification of the limestone with layers of coal, but the paper before them cleared up those doubts and questions at once; for if the members would read that paper through, they would find that the carboniferous system ran through and became divided altogether by the stratification of the coal and limestone measures.

Mr. John Young, Hunterian Museum, University of Glasgow, said he had listened with very great pleasure to Mr. Geikie's paper, and could say that it described very fully and faithfully the subject of which it treated. He had himself been a geological worker in the Scottish coalfield for the last 24 years, and could, therefore, bear testimony to the truthful description that Mr. Geikie had placed before them, of the various divisions into which the coalfield was split up. The various phenomena which attended it were very different to those observed in England, Ireland, and other countries where carboniferous limestone strata prevailed. Mr Geikie had shown them that Scottish fields had been divided by strata of many kinds, indicating particularly shallow seas, brackish waters, fresh-water lakes, and old land surfaces. In England, Ireland, and other countries, deep seas had prevailed during the deposition of the limestone series. Mr. Geikie had pointed out the great development of lower coal measures all over the Scottish coalfield, the strata of which were of great interest to those who were desirous of studying the phenomena of that district. Besides the upper coalfield proper, there were the calciferous sand-stone series of coal-bed and oil-shales, and beds of coal deposited in the carboniferous limestone series, in all of which might be found indications of the various changes from old land surfaces to sea and lake bottoms during their formation. Even among the igneous rocks themselves there were indications of coal forests having existed, and of those coal forests having been changed into beds of coal. Such instances occurred near to their own neighbourhood. Within the last few days he had made an interesting examination of one or two such coal beds. The beautiful trappean hills of Bowling were familiar to those who were acquainted with the scenery of the Clyde. In these hills might be found seams of coal, showing woody structure and beds of shale, where plants were beautifully preserved, imbedded amongst the trappean ashes. He had no doubt, that from the specimens obtained, the character of those coal plants would yet be determined with a greater degree of exactness than any others yet found in the Scottish field. There were seams of coal in the hills, that would be found to vary from a few inches to several feet in thickness, but they were all of an impure quality and were only interesting in a geological point of view. They had been formed under various circumstances. In some cases they were deposited between layers of shale, in others

between the various beds of trappean ash. The plant beds he referred to were those lying in the shales beneath the coal beds, and there the plants had all been finely preserved. This was sometimes found to be the case elsewhere—as in the Island of Arran—among the trappeans connected with the lower carboniferous strata, and those who wished to obtain an insight into all the geological phenomena of the Scottish coalfields, and wherein they differed from those in other countries, had an interesting history to read to acquaint themselves with the building up of this series of deposits. That all the igneous rocks which form these hills were not poured forth at once was clear. There must have been periods of repose between the various stages, sufficient in some instances to permit a forest, or vegetation of some kind, to grow over the surface; and in other tracts fresh-water lakes had covered the surface in which fishes had swam over the deposits forming in the lakes, and plants had grown upon the borders of the shores. One of the pictures before them presented a very clear idea of what the scenery in Scotland may have been during the deposition of the Scottish carboniferous series. They had the plants growing upon the borders of the lake which now form coalbeds, and in the lake itself the deposits in which the fishes had been imbedded by the various processes that had gone on. This was not the case in any one single part of the coalfields, but he believed that somewhat similar conditions would be found wherever the igneous rocks to which he referred were fully explored. Many parts of the Scottish coalfields were as yet comparatively unknown. He was very much pleased to hear Mr. Geikie so faithfully and fully describe all the conditions of the strata in the Scottish coal-formation, as those conditions corresponded exactly with what he himself had often observed.

Mr. Whitley, Leeds, having made a few remarks,

The President said he need not enlarge upon the subject further than had already been done. It was one of deep interest to them all, and he was sure that the paper had been highly appreciated—also the remarks that had been made upon it. He had now only to ask them to give a vote of thanks to the author.

The meeting was then adjourned until the following morning. During the day the members visited the works in the neighbourhood of Glasgow.

WEDNESDAY, 7TH AUGUST, 1872.

The proceedings were commenced by the reading of the following paper:—

ON THE RISE AND PROGRESS OF THE IRON MANUFACTURE IN SCOTLAND.

BY JOHN MAYER, F.C.S., GLASGOW.

IN committing to me the duty of preparing a paper on the subject set opposite my name in the official programme, the local committee for receiving the Iron and Steel Institute on the occasion of its first meeting in Scotland, have placed me in a highly honourable position, and one to which, in a sense, I have no claim, not being practically a member of the iron trade. Any fitness for the duty which I may possess is due to the fact that I have devoted a good deal of attention to the science of metallurgy, and more especially the metallurgy of iron, and that for some years I have been identified with the subject from a literary point of view.

While prosecuting my enquiries, I have become possessed of a large amount of historical and statistical information, much of which is of a very interesting character, and for which my best thanks are due to many gentlemen who have cheerfully supplied me with details in writing or otherwise. My duty on the present occasion is not to present you with those details, but rather to attempt to give the briefest condensation of them that I possibly can in the short space of time allotted to me.

Iron-smelting in Scotland dates back to the year 1760. It was in that year, and on the opening day of it, that the first blast furnace was blown in at Carron Iron Works, an establishment that has ever since held a prominent place in the annals of the Scottish iron trade. The original partners in the Carron Company were Dr. John Roebuck and his two brothers, Samuel Garbet (who was in partnership with Roebuck in a chemical factory at Prestonpans, established in 1749), and several members of the well-known Cadell family of Cockenzie, a fishing village in East Lothian. Dr. Roebuck was the moving and guiding spirit in this new industry in Scotland.

He ranked high as a man of science, especially so in chemistry and metallurgy, the principles of which he constantly aimed at applying in manufacturing industry. Carron was selected as the site of the works on account of the abundant water supply, and the immense deposits of ironstone, coal, and limestone in the immediate vicinity of the village. At first there was only one blast furnace; other furnaces were soon afterwards erected, in which improved plans were adopted, and the production steadily increased. Charcoal was used as the fuel for some time, but by bringing improved blowing machinery into requisition, the pit coal wrought in the neighbourhood of the works was made available for smelting purposes. The blowing apparatus referred to was contrived by Smeaton, the eminent engineer, and was the most perfect of its kind then in use. According to Scrivenor,* it consisted of four iron cylinders 4 ft. 6 in. diameter, exactly fitted with pistons, and so contrived that the strokes of the pistons, being made alternately, produced an almost uninterrupted blast. The pumps were worked alternately by means of a powerful water wheel, which had four cranks upon its axis, each of which moved the piston of a cylinder through its stroke of four feet six inches. By this arrangement, some little pause was rendered perceptible between the strokes of the blast, but it was so trifling as not to produce any sensible effect upon the working of the furnace. There was thus obtained a larger volume of air and of greatly increased density, and its effects were soon seen in the increased yield of the furnace; for, instead of ten or twelve tons, which was its former yield per week, it rose to forty in the same period, and, on the average, 1,500 tons of iron were made per year. Carron Works soon became the most famous ironworks in Europe. Indirectly they led to the construction of the Forth and Clyde Canal, which was ultimately carried out as designed by Smeaton and Brindley. It was at Carron, or, rather, in the immediate vicinity, that James Watt, in association with Dr. Roebuck, erected his first steam engine, the patent for which was secured in the year 1769; and in that year, too, the first carronade, the invention of General Robert Melville, was cast at Carron Foundry, from which, indeed, the new form of cannon derived its name. The manufacture of carronades was long the specialty of Carron Iron Works, and it was in a great measure owing to the

* History of the Iron Trade.

extraordinary extent of this branch of the business during the wars that the proprietors of the works made such fabulous profits.

Mr. William Cadell, junior, was the first manager of the works. He was succeeded by Mr. Charles Gascoigne, son-in-law of Samuel Garbet, one of the original partners; but Gascoigne was tempted, in or about the year 1786, in the reign of the Empress Catherine II. of Russia, to take service under that monarch, who desired to have ironworks erected in her dominions, for the purpose of manufacturing cast-iron guns, cast-iron shot, and shells. He took with him, although contrary to law, several skilful workmen from Carron, one of whom, so recently as the year 1838, and enjoying the rank of General in the Russian service, was the manager of the ironworks and cannon-foundries established by Gascoigne. Another, a Knight of the Russian order of Vladimir, was at the same time manager of a large factory established at Cronstadt for the production of muskets, steam engines, and other iron goods. When Gascoigne left Carron, the works were placed under the management of Mr. Joseph Stainton, a native of Cumberland, who had been for several years employed in the counting-house of the Carron Company. It was more especially owing to Stainton's great business powers that the affairs of that company attained that prosperous condition for which they were specially noted during several decades of the present century. About the year 1829, or 1830, Stainton was succeeded in the management of the works by his nephew, Mr. Joseph Dawson, and in the Dawson family the control of the works is still continued.

Sir John Sinclair, writing in 1792, said the Carron Works then consisted of five blast furnaces, sixteen air furnaces, a clay mill for grinding clay to make bricks for the use of the said furnaces, an engine raising four tons and a half of water at one stroke, and, on an average, making seven strokes in a minute, its consumption of coal being sixteen tons in twenty-four hours. There were three cupola furnaces, four boring mills, for boring guns, pipes, cylinders, &c.; smiths' forges, for making large anchors and anvils, as well as small work of various kinds; a forge for making malleable iron, a plating forge, and a forge for stamping iron, the hammer and helve of which were both of cast metal, and weighed a ton and a half. It will thus be seen that, although Carron acquired its reputation for the pig iron made at the works, and more especially for the

extent, variety, and excellency of its foundry products, it preceded all other ironworks in Scotland in the manufacture of malleable iron. So far as I can learn, there were never more than five blast furnaces at Carron, and they were of such limited capacity that the production was never large, if we compare it with that of some furnaces now working in Scotland. It is interesting to note that, with the exception of the Cadells, the originators and early managers of Carron Iron Works were all Englishmen, and this is true even of almost all the skilled artizans employed at the works; and it is also worthy of remark, that persons trained at Carron became the practical managers of other important ironworks, which were soon afterwards established in Scotland. The original contract of the Carron co-partnery, stipulated that the capital of the company should not exceed £12,000; in 1771, however, an addition was made to the contract, and one alteration was, that the capital should be raised to £130,000 forthwith, and afterwards to £150,000 in 600 shares of £250 each. In the year 1773, these and other arrangements were legalised by a Royal Charter, granted by the King for the incorporation of the company.

The first attempt at ironmaking in Scotland, after that just briefly noticed, was made at Bonaw, in Argyleshire, in or about the year 1763. It was quite successful. One furnace was set going, the blast being driven by water power from the River Awe. The mineral used was (and still is, for the Lorne establishment yet exists) hematite ironstone from Lancashire; and now, as at first, both the cold blast and charcoal are used in making the Lorne pig iron, which for the purpose of conversion into crucible steel is quite as reliable as the best Swedish or Russian brands. This is the only instance of charcoal pig iron being now made in Scotland. There was another similar furnace in the year 1790 at Goatfield, also in Argyleshire, but when it was commenced I have not been able to learn.

A much greater amount of importance is claimed for the works established at Wilsontown or Cleugh, in the Upper Ward of Lanarkshire, near the boundary of Mid Lothian. They were commenced in the year 1779, by two brothers named Wilson, Swedish merchants in London, but Scotchmen by birth, and natives of the parish of Carnwath, in which the works were erected. Messrs. Wilson began in 1774 to work coal in the district, and soon afterwards set up a foundry.

Their first blast furnace commenced operations in 1780-81, and their second in 1787. The business, which was practically the same as that pursued at Carron, was carried on for several years with great spirit, and Wilsontown rose into considerable importance. An extensive forge was started, and when the works became the sole property of Mr. John Wilson, sen., in 1798, the forge was increased in extent, and in 1804 a rolling mill was erected. From 1812 till 1821 the works were stopped; in the latter year Messrs. John and William Dixon became the proprietors. They were carried on for many years by the Messrs. Dixon, and by the experiments pursued during their occupancy of the works both Wilsontown and the Messrs. Dixon occupy a prominent position in reference to the Scotch iron manufacture. It was here that the possibility of using raw coal in the blast furnace was first solved, which may certainly be regarded as one of the grandest epochs in the history of the iron manufacture. At Wilsontown, likewise, but in the time of Mr. John Wilson, probably in the year 1803 or 1804, the much-debated question of entangling moisture in the air of the blast by passing it over a sheet of water was completely settled, if the results of rigid and crucial experiments upon a large scale are to be depended on. Such experiments were instituted by Mr. Wilson, and that gentleman thoroughly demonstrated the inutility of the moisture, and the superiority of dry over humid air in the blast furnace. It was at the Wilsontown Works that, in the year 1808, the water tuyere was brought into use to supersede the dry tuyere: and, many years afterwards, a manager of the same works under the late Mr. Dixon, namely, Mr. Condie, devised and perfected the tuyere which is now universally employed, and which owes its great utility to the spirally-disposed malleable iron tube contained within a mass of cast iron. The Wilsontown Works ceased operations in the year 1842.

About the year 1787, ironworks were commenced at Muirkirk, in Ayrshire, and at Omoa, in Lanarkshire, a few miles from Wilsontown. The works at Omoa no longer exist, but it is intended to continue the place as a seat of the iron manufacture, that being the site fixed on for the erection of an establishment where the Danks puddling furnace is to be used on an extensive scale. Muirkirk has a much more interesting history than Omoa. Very early in its history it became famous for its bar iron which was little, if

at all, inferior to Swedish iron. For many years the Muirkirk bar iron was exclusively hammered iron, and it was so excellent that in South Wales rolled iron was made and finished to imitate it even to the extent of the brand. I find from private documents that in 1809 this Muirkirk hammered bar iron sold at £20 per ton in Glasgow, the higest price being £21 in 1825, and the lowest £14, at which it was sold in 1823, and again in July, 1829, when it was completely superseded by ordinary rolled iron which, of course, could be produced much more cheaply. While speaking of the price of Muirkirk bar iron, it is worthy of notice that the lowest-priced pig iron ever produced in Scotland was made at the same works, its selling price in Glasgow, after being carted nearly thirty miles, being 35s. per ton, and even at that rate it left a margin of profit. The cost of the minerals was necessarily very small. The lordship paid for the coal was only 1d. per ton, and for the ironstone 3d. per ton. Muirkirk had two blast furnaces erected and at work in the year 1796, making 2,878 tons of pig iron per annum; in 1826 there were three furnaces making 5,000 tons per annum.

In the following year, 1788, Clyde Iron Works, near Glasgow, were erected by Messrs. Edington and Co., for the production of pig iron. No person who is engaged in the iron trade, and knows anything of its history, can hear the Clyde Iron Works spoken of without instantly calling to mind the names of two of the most conspicuous characters that the Scotch iron trade can boast of: they are David Mushet and James Beaumont Neilson. The former entered the works as accountant, in 1792, when he was nineteen years of age, and left in 1800, but becoming in the interim one of the most skilful assayers of his time. While engaged in the following year in the erection of Calder Iron Works for himself and partners, the chief of whom was the elder Mr. William Dixon, of Govan, he made the discovery of the blackband ironstone,—a discovery to which we may trace a large share of the influence which Scotland has since acquired in the iron manufacture.

The other character just named was bred as an engineer, and in the year 1817, when he was twenty-five years of age, he became foreman to the Glasgow Gaslight Company. After he had become thoroughly established as a gas-works engineer, his professional advice began to be in request among ironmasters, and especially was he consulted by Mr. Dixon at Wilsontown Iron Works, and by

the Muirkirk Iron Company. The insight into blast furnace management, which he incidentally acquired, led him to institute experiments to test the effect of blowing heated rather than cold air into the furnace, and he found that a very marked change took place, both as to the increased quantity of iron yielded at each casting, and the diminished quantity of fuel required in the smelting operations. Mr. Neilson's crucial experiments were carried out at Clyde Iron Works, when the proprietor was Mr. Colin Dunlop. They ultimately led him to secure a patent for the improvement which seemed to be within his grasp. That was in the year 1828. By his hot-blast invention he proved himself to be one of the greatest benefactors that the world has yet seen in the domain of the industrial arts and manufactures, and well entitled to be bracketed along with Henry Cort and Henry Bessemer. It is scarcely necessary, in such a meeting as the present, to enlarge upon the various circumstances connected with the earlier experimental investigations instituted by Neilson, the difficulties which he had to contend with, the prejudices which he successfully surmounted, and the great industrial revolution which was effected by the adoption of his process; nor need we speak of the various litigations, both in England and Scotland, which Neilson and the co-proprietors of the patent had to institute in order that his patent rights might be preserved intact. One who, like the writer, takes upon himself the duties of the historian, even in a limited sense, naturally feels somewhat pleased that the validity of the patent was called in question in such a way as to lead to the great trial which took place in the Court of Session, in the month of May, 1843, as there was placed on record a large amount of the most valuable information, in the shape of evidence from scientific and thoroughly practical men, that might otherwise have been lost to the world.

The great value of the hot-blast invention may to some extent be judged of when we mention that raw coal could be substituted for coke in the blast furnaces, and that a saving of coke to the extent of five tons per ton of pig iron, and half a ton of limestone, was effected by its employment. Taken in conjunction with Mushet's discovery of the blackband ironstone,—by using which a furnace working on the hot-blast, and making sixty tons of iron per week, had its production raised to eighty or ninety tons,—Neilson's invention became, in the language of Mr. Houldsworth, "the making

of the iron trade of Scotland." In 1827, the year before the hot-blast patent was taken out, the make of pig iron in Scotland was about 36,000 tons, but in the year 1843, when the patent rights had terminated, it had risen to 280,000, or 300,000 tons.

Calder Iron Works, as already indicated, were commenced in the year 1801. They occupy a somewhat prominent position in the history of the Scotch iron manufacture, inasmuch as it was there that the blackband ironstone was first used as an ore of iron, and its great value practically demonstrated. At Calder, and Wilsontown likewise (the latter it may be remembered belonging to Mr. Dixon), Neilson's hot-blast invention was early put to the test, and such material aid was rendered by Mr. Dixon, and his accomplished manager, the late Mr. Condie, in working and developing the merits of the invention, that the proprietors of the patent freely granted the use of the patent for several of the Calder furnaces without exacting the usual royalty charges.

Retracing our steps a little geographically, we have now to go to the north of the Forth, where we find that about the same time as Calder was started, iron-smelting was commenced in Fifeshire, at Balgonie, near Markinch, on the Leven. It may be of interest generally to the visitors from the North of England to learn that this enterprise was due to Messrs. Losh & Wilson, now Losh, Wilson, and Bell, of Newcastle-upon-Tyne. Much expense was incurred by the firm in carrying out the enterprise. The scheme had a sufficient trial, but it ultimately proved to be unsuccessful, and after suffering much loss, Messrs. Losh & Wilson had to abandon the undertaking. A Fifeshire ironmaster informs me that some remains of the furnace, the buildings for the water wheel, &c., were in existence within the last twenty years, and that the works seemed to have been well got up in every respect. The ironstone could not be smelted profitably at Markinch, but it was afterwards used for many years both at Carron and on the Tyne. That was, of course, in the pre-Cleveland times, before John Vaughan had stumbled upon the traditional boulder on the Cleveland Hills.

The only other iron-smelting establishment north of the Forth having any special interest attaching to it, is one that was commenced in the year 1792, near Clackmannan, on the river Devon, by Messrs. Roebuck & Longridge. Whether or not the first-named partner was the brother or son of Dr. Roebuck, the founder of the

Carron Iron Works, I have not been able to learn. The Devon Iron Works were peculiarly interesting from the fact that the furnaces, of which there were three, were cut out of the solid rock and lined with fire-brick, and that they were provided with the largest air vault ever used at an ironworks for blast purposes. This vault was also excavated out of the solid rock. The iron made at Devon Iron Works was of a very superior quality. For about six years (1848-1854) these works were managed by the late Mr. Alexander Christie, his partner being Mr. John Wilson, of Dundyvan. During that time Mr. Christie laboured most assiduously to accomplish the utilisation of the gas produced in a furnace using raw coal. He was successful, but his success was gained at the expense of the quality of the iron. Nothing but hard iron could be produced, no No. 1, partly on account of the small height of the furnace and the irregular way in which it worked. The works were ultimately stopped and dismantled about fifteen years ago.

From the beginning of the century till the hot-blast invention was announced, very little progress was made in Scotland in the iron manufacture, and but very few new works were started or projected. Shotts started into existence in the year 1802, under the management of Mr. John Baird, of the Canal Basin Foundry, Glasgow, who continued to be the managing partner for upwards of forty years. Within the last two or three years, the Shotts Iron Works have entered upon a new lease of existence, and it is fully intended to rebuild two of the furnaces upon the most modern and approved principles. Another evidence of the progress now making at Shotts is the regular production of Bessemer pig iron from hematite, by the use of raw coal. Monkland only started with its first blast furnace in the year 1825; now, however, the manager of that well known establishment, Mr. Ferrie, formerly of the Forth Iron Works, near Dunfermline, is the recognised leader in blast furnace practice. Gartsherrie, which has long bulked largely in the iron trade, is even more recent than Monkland, its first furnace being put in blast in the year 1830, at which time Neilson's invention was in practical operation, and had therefore been stamped by public approval.

Clyde Iron Works formed a sort of school in which blast furnace managers were bred. We have already spoken of Mushet's connection with Clyde, and we ought to have mentioned that Mr.

Ferrie received his early training there. At the same works, too, John Wilson was pursuing his career as practical manager when Neilson was prosecuting his early investigations and experiments preparatory to taking out his patent. Mr. Wilson took a deep interest in those experiments, and was a willing coadjutor with Neilson in performing them; and this was the man who shone so prominently afterwards as "John Wilson, of Dundyvan." He and Mr. Colin Dunlop, of Clyde Iron Works, both part proprietors of the hot-blast patent, became co-partners in the establishment of Dundyvan Iron Works in the year 1833. In a few years Mr. Dunlop died, and, on becoming sole proprietor of the works, Mr. Wilson greatly extended them, and erected a large addition for the production of malleable iron,—the total cost of the works when the extensions were completed being little short of £300,000, and the works in their entirety being the largest of the kind in Scotland. During his time, Mr. Wilson was ever anxious to avail himself of every approved new process or appliance in the iron manufacture. It was at Dundyvan that the cylindrical form of shaft was first adopted for blast furnaces, and Mr. Wilson actively encouraged every feasible attempt at collecting and utilising the blast furnace gases. Before his death, which occurred in 1853, he had erected four blast furnaces at Kinneil, near Bo'ness; had, in conjunction with Messrs. Dunlop, of Clyde Iron Works, built the Lugar Works, of which he afterwards became the sole proprietor; and was one of five partners by whom the Muirkirk Iron Works were acquired and carried on. They all remain yet, but the great Dundyvan is blotted out of existence.

Amongst the other important works commenced during the currency of the hot-blast patent, we specially mention Coltness and Summerlee Iron Works (both of which date back to 1836 or 1837), and Langloan Iron Works, which were started in 1841. The management in each instance is marked by the spirit of progress, and especially is this true of Summerlee, at which establishment the principle of gas utilisation is being pushed on with something like the energy that is manifested among the Cleveland ironmasters. Coltness may be said to hold the very front rank in Scotland as regards the quality of its iron, and it is now finally resolved by the management to go in for economical production by the application of the bell and cone to at least two of the blast furnaces; and Langloan cannot long remain behind.

Of the works established in Scotland since the patent expired we need only name or specially refer to two. One of these is the Almond Iron Works, in Linlithgowshire, under the energetic management of Mr. Henry Aitken; and the other is the Glengarnock Iron Works in Ayrshire. At the former, the great height of one of the furnaces is the special feature. The blast furnace in question is seventy-two feet high, while no others in Scotland, perhaps, with the exception of the Ferrie furnaces at Calderbank and one at Summerlee, stand more than sixty-two feet high, and many of them are under fifty feet. Mr. Aitken's tall furnace works exceedingly well. At Glengarnock successful efforts have been made to collect and utilise the furnace gases, one of the furnaces being closed on the bell and cone system, and two of them being open-topped, but yielding, by means of suitable arrangements, about one-half of their gaseous products.

The temperature of blast employed in Scotland rarely exceeds 800 degs. Fahr.; at one or two works, however, it is claimed that the blast reaches to 900 degs. or even 1,000 degs. Certainly none of the high temperatures employed by Mr. Charles Cochrane and Mr. Thomas Whitwell have met with practical approbation among ironmasters in Scotland. Blast stoves on Cowper's and Whitwell's plans are still unknown at the Scotch ironworks.

On the question of consumption of fuel in the blast furnace, it may be stated that the average consumption in one instance where four furnaces were tried for a whole year, has been reduced to rather less than 36½ cwt. per ton of pig iron; and at Summerlee it is from 49 to 50 cwts. per ton of pig iron. Mr. Henry Aitken, working his coked ironstone as part of his charge, finds that a ton of pig iron is made in his tall furnace by 20½ cwt. of coke; while in a low, or 50 ft. furnace, the amount required is 25⅔ cwts. of coke.

The weekly production of pig iron in Scotland varies generally between 150 and 200 tons per furnace, and the average amount may be taken at about 178 tons. There are 154 furnaces built, and 129 at present in blast. The greatest number in blast at any time was 134, and the greatest yearly make of pig iron was 1,206,000 tons in the year 1870, the make last year being 1,160,000 tons, or a decrease of 46,000 tons. Shall we say, therefore, that Scotland has attained its maximum of productive power? We fear that we have not yet accumulated sufficient reliable data on which to found

an opinion. A marked feature in connection with the Scotch iron trade is the very large stocks that have been kept for many years, especially in Glasgow They were no more than 80,000 tons on 1st January, 1848, but, with some fluctuations, they rose to nearly three-quarters of a million tons (763,000) on 1st January, 1864, since which time there has been an enormous decrease. Makers' stocks are now reduced very low, and the stocks in the public stores, which were fully 372,000 tons at the end of last year, have now been reduced to less than 200,000 tons.

Our remarks hitherto have been almost entirely confined to the production of pig iron in Scotland, but besides the works already named, such as Muirkirk, there are many establishments in which the manufacture of malleable iron is carried on. Muirkirk, in the hands of its present proprietors, Messrs. Baird & Co., still continues this branch of the iron trade with marked vigour. Monkland and Govan (Mr. W. S. Dixon) are also largely engaged in it, as well as in producing pig iron. Practically, there is only one other firm in Scotland, namely, the Glasgow Iron Company, whose business includes both branches of the iron trade. The malleable ironworks are confined within a very limited area, if we exclude Muirkirk from our calculation. We have several in Glasgow, and the remainder may be said to be confined to the district extending from Coatbridge to Wishaw, and including both. The largest and most completely equipped establishment in Glasgow is Blochairn Iron Works (Messrs. Hannay & Sons). Of the others we may specially mention the Glasgow Iron Works and the St. Rollox Iron Works, both belonging to the Glasgow Iron Company, and Parkhead Forge. In and around Coatbridge there are the Coats Iron Works, the Phœnix, the Clifton, the North British, the Tinplate Works, and several others. A short distance from Coatbridge, besides the Monkland Company's Works, there are the Mossend Works and the Clydesdale Works at Holytown, and two or three miles further on the Caledonian main line there are the Motherwell Works of the Glasgow Iron Company, and the Dalzell Works, near Motherwell.

There is only one establishment, namely, Parkhead, that lays itself out to make armour plates; but ship plates and boiler plates are made extensively at several works; and, with two or three exceptions, they all turn out various kinds of general merchant iron. The productive power of the various works differs very considerably,—from

5,000 or 6,000 tons of finished iron per month, down to 2,000 tons, 1,500, 1,000, 800, 650, 550, and so forth. The total make last year was 200,130 tons, and this year's will probably be greater, inasmuch as the works are both increasing in number and, in some instances, in productive capacity. It is very difficult to get correct information regarding the total number of puddling furnaces at work, or available for use in Scotland, owing to the almost incessant change which is going on, and has been in progress during the last few years; here, new forms of furnace being substituted for the old familiar friend, and there, after incurring a large expenditure of money, time, and mental anxiety, the furnace of the ordinary type re-assuming its place, while the so-called improved furnaces have been discarded and dismantled. The Scotch ironmasters, equally with the rest of their countrymen, have the reputation of being "canny," but they certainly cannot be charged with a persistent determination not to give a trial to every form of furnace and mode of using fuel that seems to have in it the elements of success. Even the most recently projected variety of furnace, the Dormoy, has found in Mr. Ellis, of the North British Iron Works, Coatbridge, a gentleman who is quite ready to step into the breach at the present critical stage of the iron trade, and, for his own satisfaction and that of his brothers-in-trade, to practically test its claims to be considered a real step in advance in the direction of mechanical puddling. As regards the question of using gaseous fuel in puddling and heating furnaces, it may be mentioned that both the Siemens and the Gorman methods have been extensively put on trial. The former, notwithstanding its extraordinary scientific merits, is going out of favour, but the latter, after a persistent effort on the part of its inventor to render it as perfect as possible, is becoming more and more popular, especially for heating purposes. It is quite a local invention, and besides being used in several finished ironworks in Scotland, it has been most extensively adopted by the Clyde shipbuilders, and has also found its way across the Border to Sir William Armstrong's works, and to the new shipbuilding works at Barrow-in-Furness. So far as I can learn, the most recent economical result of applying the Gorman principle to a mill furnace is the production of one ton of rolled iron by the consumption of $3\frac{1}{2}$ cwts. of dross. But I rather think that the fuel required to generate the steam for the blast-fan is not included in the amount just given.

In the department of mill-mechanism progress is also being made. The lever-clutch arrangement for reversing rolling mills is applied to two mills at Mossend; Blochairn and Monkland have adopted Mr. Graham Stevenson's friction cone appliance; Parkhead Forge will soon afford a local example of the application of the friction-clutch arrangement devised by Messrs. Napier Brothers; and Mr. Ramsbottom's method has found favour with Messrs. Bain and M'Corkindale to the rejection of all the others. But as these various systems will doubtless, at this meeting of the Institute, be fully considered by practical men, I need not any further trespass upon your patience and good nature than by simply stating, in conclusion, that the manufacture of steel, as well as finished iron, has also become established in Scotland. Both Bessemer steel and crucible steel are made in Glasgow, and in the course of a few months steel will also be manufactured in this locality by the Siemens-Martin process.

The President said that the very interesting paper to which they had just listened would, he thought,—from its essentially historical character—scarcely give them an opportunity for discussion; he believed that no one then present would feel inclined to dispute the general facts which had been very fully set forward in the paper, and he begged to convey the thanks of the meeting to Mr. Mayer.

Mr. E. Windsor Richards (Ebbw Vale) would like to ask Mr. Mayer one question, as he was not sure whether he had heard his remarks correctly. Did he understand him to say that raw pit coal was first used for smelting purposes in Scotland?

Mr. Mayer believed, that as raw coal, that was the case.

Mr. E. Windsor Richards (Ebbw Vale) said they had always been taught, and it had never before been questioned, that raw coal had been first used in the smelting of materials in the blast furnace at Coalbrookdale, Shropshire, by the grandfather of the present Mr. Abraham Darby.

Mr. Mayer rather thought that it was coal converted into coke in every instance, until Mr. Dixon succeeded. Dud Dudley also, of course, got the credit for using pit coal, but it was used as coke.

Mr. Menelaus would not take up the time of the meeting further than to remark that he had often said, the great use of meetings like the present was to take the conceit out of a man, and he would

confess that this meeting had taken the conceit out of him, for he, like his friend who had just spoken, had believed that Darby was the first who had succeeded in using raw coal in the blast furnace, but he supposed that after what they had heard that morning, they must give up that idea. As a Welshman, he had thought that the cheapest pig iron ever produced had been made at Beaufort, Nantyglo, with blackband, but when they heard of pig iron having been sold at a profit, at 35s. per ton, after having been carted thirty miles, he must disabuse his mind of the notion that cheaper pig iron had been made in South Wales than in Scotland, because unless they fed the horses on sawdust, the iron must have been produced at the furnace at something about one pound (£1) a ton, and in Wales they had never equalled, nor even approached that cost, not even in the grand old times.

Mr. J. R. Napier thought Mr. Mayer said that the pig iron was sold, but not that it had been sold at a profit.

Mr. Menelaus replied that if it were merely sold, and not sold at a profit, of course his observations were not applicable.

Mr. J. R. Napier further said that his father happened to be the proprietor of an ironworks at the period to which Mr. Mayer had referred, and he knew that the iron had then been sold in Glasgow at a loss.

Mr. Edward Williams, like Mr. Menelaus, had been abashed when he heard that pig iron in Scotland had been sold for 35s. per ton, and a profit was made, notwithstanding that the iron was carted thirty miles. It now appeared that the iron was sold below cost price, which he would not have thought possible, but for Mr. Napier's assertion that such was the case. Mr. Mayer had been so good as to ask whether it was within his (Mr. W.'s) knowledge that iron had been made in South Wales a long time ago, rolled, then hammered, to make it appear as though it were hammered iron, and stamped with the Muirkirk brand. He begged to say that no such operation as that was within his knowledge, and he very much questioned the statement made. For over a quarter of a century he had been connected with a make of Welsh iron, which, with its own honest brand G.L. upon it, had found no inconsiderable favour even in Scotland, and it was only the truth to say that the best brands of Welsh bar iron did very well by themselves, without needing to assume a stamp in imitation of Muirkirk or any other

place. A matter referred to by Mr. Mayer ought, he thought, to be put in a proper light, that was, the stumbling by Mr. Vaughan over that wonderful piece of ironstone of which they heard so often. That story had gone the round of papers and books for the last twenty years or so. It was stated that Mr. Vaughan, when shooting, "stumbled"—as Mr. Mayer had put it—over a nodule of ironstone, that he at once saw the value of it, and from that time began the iron trade of the Cleveland district. He had, however, the authority of Mr. John Vaughan himself for saying that there was no truth in the story. The ironstone had been known for a long time; it had been sent to various places to be tried,—he did not know before to-day that any of it had come to Scotland,—and wherever it was tried it was declared to be of no use whatever. To Mr. Vaughan was due the great credit of having reversed that decision, and of having founded the most extensive and rapidly extending section of the British iron trade.

Mr. Mayer wished to make one remark, viz.—that in the particular case he had quoted—he was not aware whether it was during the proprietorship of Mr. Napier's father or not—the iron had certainly been sold at a profit of 6d. per ton. It was made at a cost of 25s. at Muirkirk, the cartage cost 9s. 6d., and it was then sold in Glasgow at 35s.

NOTE.—The question of the priority of using raw coal in the blast furnace having been raised in the discussion on my paper, I have since looked up Dr. Percy's sketch of the Darby family ("Metallurgy: Iron and Steel," p. 888) and find that Abraham Darby, 1730-1735, "determined to treat pit-coal as his charcoal-burners treated wood," * * * and that "having thus made a good stock of coke, he proceeded to experiment upon it as a substitute for charcoal."

"Ure's Dictionary of Arts, Manufactures, and Mines" (6th Ed., 2nd vol., p. 699) also says that "carbonised pit-coal was, till within the last twenty-five years, the sole combustible used in the blast furnace." I do not know when the article was written, but the title page bears date 1867.—J. M.

The following paper was then read:—

NAPIER'S DIFFERENTIAL FRICTION GEAR FOR REVERSING ROLLING MILLS.

By R. D. NAPIER, GLASGOW.

THE principle of this reversing gear is simple enough, but it is not easy to explain the arrangement without the use of models. I therefore have not thought it worth while to trouble you with drawings, nor even with a detailed description, but hope those who

may be interested in the subject may examine the models which lie on the table.

These models illustrate, in the first place, the foundation or main-spring of the Differential Friction Gear; in the second place, the application of the principle for the purpose of driving machinery in one direction only; and thirdly, the arrangement for reversing machines.

What I have called the mainspring of these arrangements is a friction brake, which can be so adjusted as to be perfectly self-holding, and yet can be easily slacked.

These self-holding brakes are now used extensively in the windlasses of steam and sailing vessels for riding by, and especially in those of the largest class of steamers; and I believe I am correct in saying that there has never been an instance of any of them being in any way injured, though often subjected to severe trials.

It may be recollected that the steamer which lately took the "Livingstone Search Expedition" to Zanzibar was the only vessel which rode out a hurricane there. That steamer, the "Abydos," was one of some 150 vessels at anchor there, and she rode out the hurricane by these self-holding brakes; and the captain has written us, that though the chains were so badly strained that they had to be sent ashore to be repaired, the windlass was not strained in the least.

The models I have referred to, in the second place, represent a single-acting differential friction clutch, which is an arrangement for driving machinery through the instrumentality of a differential friction brake. It is used for driving machinery that has to go in one direction only, and which has to be stopped and started while the shafting or wheel-work that transmits the power is in continuous motion.

The model referred to in the third place is that a pair of reversing differential friction clutches, such as we apply for working planing machines, bending rolls, and other reversing machines of comparatively moderate size; and the only difference between this arrangement and that which we are now supplying for reversing rolling mills, is the introduction in the latter of what we call a thrust-block between the differential lever and the friction wheel, which takes by far the largest part of the strain off the driving or crank-pin, and communicates that strain to the friction wheel,

which enables us to reduce the strength of the friction straps by one-third. We introduce this thrust-block whenever any great strain has to be transmitted. We have made a considerable number of these comparatively smaller class of reversing clutches, which have been very successful; but have only as yet supplied two pair for rolling mills, and of these one pair supplied to the Woolwich Arsenal are not yet started.

The other pair have been at work for nearly six months at Codnor Park Iron Works, belonging to the Butterley Company, and to Sir John Alleyne, Bart., the manager of these works, we are indebted for the opportunity of making a first trial of the plan of gearing I have been referring to for reversing rolling mills.

We have now in course of construction a 26-inch rolling mill for Messrs. Beardmore, of the Parkhead Forge, which we were very much in hopes to have started before the meeting of the Iron and Steel Institute in Glasgow. In Messrs. Beardmore's mill we are introducing a novelty in this class of work, and one which many, I may say most people, think will not do, but we have great confidence in the result; we are putting the reversing gear on a pinion shaft going at 91 revolutions, the rolls themselves making 26, and we have, therefore, to reverse the wheel and pinion at those velocities. We have never yet done anything of this sort nearly so large, but our reversing gear has been at work at Messrs. Caird's Shipbuilding Yard at Greenock, driving bending rolls, where the pinion (which is 9 in. in diameter—$2\frac{1}{2}$ in. pitch and 8 in. wide, and goes 170 to 180 revolutions per minute) is reversed each time the rolls (which are 21 in. diameter) are reversed, and it has been so successful that they have lately nearly doubled the speed of another set of bending rolls in which the pinion was going 100 revolutions, and Mr. Dickson, the manager, says the faster they go, the better they work.

With regard to this last, I may say, that so powerful and manageable is the grip of the differential brakes that we are making the friction wheels only 18 in. diameter for driving a 10 in. pinion shaft; and the advantage in cost of applying the reversing gear to the pinion in place of the roll shaft is such that we can put down the mill with our gear applied at less expense than a mill on the common plan would cost, making a clear gain of all the advantages of our reversing gear.

EXPLANATION OF DIAGRAMS.

Fig. 1 is an elevation. Fig. 2, a section through A B (fig. 1). Fig. 3, a plan; and fig. 4 a section through C D (fig 2), with the friction straps, &c., removed. Fig. 5 represents the primary differential action illustrated by the first model referred to; and fig. 6 is a differential brake suitable for supporting very heavy loads, and is the arrangement used in the rolling mill gear.

The figures in the several views refer to the same parts of the gearing. Referring first to fig. 6, between the friction wheel, 1, and the differential lever, 2, is the thrust block, 3; the central part of the differential lever works in the exterior and concave part of the thrust block, and the hole for the fulcrum pin through the differential lever is enlarged a little on the part farthest from the friction wheel, so that all the radial strain, which, without the thrust block, would be borne by the fulcrum, is taken off it and transmitted to the friction wheel.

The principal object of the thrust block is to relieve the fulcrum of the greater part of the strain that it would otherwise have to bear, but it has the secondary result of increasing the power of a given brake by about 50 per cent., for the friction of the thrust block on the friction wheel is about half-way between that of the two segments of the friction band.

Referring now to figs. 1 to 4, in which the fulcrum pin of fig. 6 becomes the crank or driving pin; the cranks 5 are keyed to the shaft, and the spur wheels 6, to which the friction wheels are attached, are loose on the shaft, and are driven in opposite directions by any convenient arrangement of wheel work.

The friction straps are alternately made to grip and release their respective friction wheels by means of the bill cranks, 7, which are worked by the sliding ring, 8, which latter is worked by the hand gearing 9, through the axle 10, on which are keyed the two levers 11.

When the sliding ring, 8, is in the middle between the two cranks, both clutches are out of gear, and if it is moved towards the one or the other crank, the one strap is allowed to grip its friction wheel, when the wheel drives its strap, and the strap the crank, by its crank pin. Though this plan of clutch is self-holding, or may be so if desired, it may, at the same time, be thrown into

gear when going at great speed without the slightest shock. In the Butterley Rolling Mill, with 22 inch rolls working at 45 revolutions per minute, the reversing takes place perfectly inaudibly, and without the least indication of any extra strain in the gearing.

The President said that the very interesting paper to which they had just listened was one of so much importance that he was sure there were many persons present who would like to ask questions upon it, and he hoped the discussion would elicit useful information. They had, however, two papers in the programme touching very much upon the same subject, the next one being, "On Reversing Rolling Mills," by Mr. Graham Stevenson, and, he thought, it was almost impossible to discuss those papers without reference to the respective merits of the two systems, and it would save the time of the meeting if they were at once to proceed with the reading of the paper by Mr. Graham Stevenson, and then discuss the two papers, after hearing the two modes described.

ON REVERSING ROLLING MILLS.

BY MR. GRAHAM STEVENSON, AIRDRIE ENGINE WORKS, AIRDRIE.

SUCCESS in the manufacture of iron, as in many other branches of industry, depends in a great measure on the mechanical appliances employed—perfection of such appliances alone enabling us to produce largely and quickly; and so keen is commercial enterprise, that each must exercise the utmost economy, in order that the product be of sufficient cheapness, and comparable with other makes of its kind and quality. We must save at all ends—in fuel, in manual labour, in time, and—more, perhaps, than in anything else—in hindrances to manufacture or output by breakages. The increasing price of labour and fuel are rapidly enhancing the cost of production in our own country, whilst every year foreign manufacturers are lagging less and less in the race. We must, therefore, have recourse to every expedient which promises to realise economy, if we are to maintain our position.

It will be generally admitted that any satisfactory system of reversing rolling mills will have great and beneficial influence in this direction, and the adoption of even comparatively imperfect arrangements have already effected considerable saving in time

and cost. In many instances, however, the advantages of the reversing system have been to some degree marred by defects in the appliances employed—these defects increasing the strains and shocks, and aggravating in some cases the waste of fuel. As was to be expected, where the desirability of a suitable arrangement was so obvious, numerous plans have been devised, many of which, after having all things promised for them, have had to succumb to practical difficulties; however, some of these plans have afforded useful lessons by rendering plainer the actual conditions involved, and have thus in some degree directed attention, and led to the successful accomplishment of desired results.

Any system to be satisfactory in reversing heavy mills must comprise means for bringing the rolls from a state of rest to the required speed in a gradual manner, without interfering with the motion of the driving power, as is accomplished with comparative ease in lighter machinery. The appliances introduced must obviate the sudden shock resulting from the employment of the ordinary claw-clutch, also the waste of power and staggering motion inseparable from the coupled reversing engines which Mr. Ramsbottom introduced. Both of these systems are defective and open to very serious objections, as is so far indicated by the expensive efforts that have continued to be made to accomplish the reversing by other modes.

It is the constant aim of all good engineering practice to prevent shocks and intermittent excesses of strain in imparting motion to all kinds of machinery; and perhaps to no kind of machinery should this principle be applied with more assiduity than to heavy iron rolling mills. I believe, however (although it may be exceptional), that some iron manufacturers have succeeded in working with claw-clutches with surprising freedom from breakages or other interruptions. Thus at the Motherwell and Mossend Iron Works, and also at Parkhead Forge, in this neighbourhood, these clutches have been in daily use for many years, and the proprietors of those works do not seem to think that their action is altogether unsatisfactory. It has been generally felt, however, where this clutch has been employed in connection with the larger and faster-going mills, that it is held in great disfavour, and as a dangerous and unsatisfactory expedient, the danger increasing as the speed is made greater and the mill larger.

It has been attempted in some instances to soften the engaging stroke of the claw-clutch by attaching cushions or buffers to the prongs, or by interposing frictional slip couplings between the pinions and the connecting spindles of the rolls, such arrangements being designed to allow of yielding to the extent of say 1-20th or 1-30th of a revolution to the blow. A somewhat successful attempt was made in this direction by Mr. Bladen, at Jarrow; and I myself formerly tried a clutch having the prongs fitted in slide boxes with rubber packing, and which yielded about 1-15th of a revolution. This plan, however, and every other attempt in the same direction has fallen greatly short of affording the amount of gradual engaging action necessary to prevent shock.

In addition to the objections to the engaging action of the claw-clutch, this appliance is open to the very serious one that it is difficult, or I may say impossible, to disengage it when a plate or bar is between the rolls, and this more particularly is the case where springs are employed. The strain, with which the claws are held in contact when at work, effectually locks them and resists severance by ordinary means; and, although the iron is seen to collar or to stray in its path, threatening breakage of the machinery or, at least, destruction of the bar or plate, there is no help for it but to let the motion continue and matters take their course.

At the Dowlais Iron Works, there is, it is true, a very fine specimen of claw-clutch at work, fitted with a cam-ring, which, by acting on a pulley when the two parts are brought into contact, presses the clutch out of gear at every reverse, or at any required moment. The parts are also arranged so that it can only be thrown into gear at the exact time to ensure the full engagement of the prongs before the mill is brought into motion, which is not always effected with the ordinary clutch. This is the most perfect working of the claw-clutch tribe I have ever seen, and the speed attained with it is probably the highest yet reached with such clutches. The diameter of the rolls is 25 inches, and the speed about thirty revolutions.

Coupled reversing engines, to which I have already referred, as substitutes for the claw-clutch, were first employed by Mr. Ramsbottom, at the Crewe Steel Works of the London and North Western Railway Co. This system cannot be adopted without giving up the undoubted advantages of the fly-wheel momentum,

because the reversing action cannot be effected with sufficient readiness unless the moment of inertia is diminished to the smallest possible amount. This system was designed by an engineer of undoubted talent and ability, and was certainly worthy of a trial; but it has been a surprise to me that the experiment should have been repeated so often, for I hold the system to be inferior to the claw-clutch with all its defects. The only thing to be said in its favour is that it is freer from the heavy percussive action of instantaneous engagement, and has therefore a less absolute liability to breakages. The wear and tear, however, and tendency to derangement are not greatly diminished, whilst the enormous waste of power, and the extraordinary unsteadiness of motion, are fatal objections. Whole cylinder-fulls of steam are thrown away on checking and reversing the motion of the engines and rolls, whilst the absence of a fly-wheel renders it impossible to work the steam expansively to any beneficial extent. The iron is borne through the rolls by the direct pressure and accumulated force of the steam, and only by means of engines much larger than what would freely do the work if aided by fly-wheel momentum. To compensate for these peculiarities, at least one-fourth more fuel is requisite, or something like 25s. have to be paid for every pound's worth of effective energy developed and employed.

On the necessity of having a sufficient fly-wheel, I may usefully refer to Mr. Walker's paper, read at a former meeting of this Institute, and reported at page 417 of the JOURNAL, on an arrangement of frictional reversing gear erected by his firm at the Blochairn Iron Works, Glasgow. The engines described have two 42-in. cylinders, and were intended to work with a high grade of expansion, being designed to actuate two 26-in. trains of plate rolls. They were at first provided with fly-wheels, amounting to 25 tons, fitted to the engine crank shaft, but this was found much too little, and they were increased to 35 tons. It is now well known that the too sanguine expectations in reference to this arrangement have fallen far short of realisation. With the original fly-wheels only one of the mills could be worked at once, and even when they were increased to 35 tons they did not act satisfactorily, the engines frequently stalling with one mill; and it being only when the fly-wheels were subsequently increased in speed and weight to more than triple in their original power, that both

mills could be worked at the same time and perform the work assigned to them, or that the elaborate expansion gear, previously quite useless, could be employed to any purpose. In short, what two coupled 42-in. cylinders, with an aggregate piston area of 2,771 in., could not do without fly-wheels, a single cylinder of that size can do with fly-wheels. In proof of this, I may mention that an engine of 32½-in. cylinder, at Mossend Iron Works, drives two plate mills, one 24 in. and the other 20 in. diameter, both rolling at the same time; and a single engine of 36-in. cylinder, with a sufficient fly-wheel, at the Monkland Works, drives a 26-in. train of reversing beam-iron rolls, and an 18-in. train of rail or merchant iron rolls. It may seem a simple matter to increase the fly-wheels' power from 25 to 35 tons, and then again to double or triple that; but the trouble, delays, and breakages which were actually due to this deficiency of fly-wheel sufficiency, amounted to something enormous, without reckoning consequential and indirect losses. The direct costs alone amounted to many thousands of pounds; and it is hoped that such costly lessons will in future cause manufacturers to pause before experimenting with inadequate fly-wheels, or, what is worse, ignoring fly-wheels altogether.

Returning to engines without fly-wheels altogether, we find in a paper read by Mr. Ramsbottom before the Manchester Institute of Engineers, that a pair of such engines, 36-inch cylinders, could turn out 12 tons of plates per shift, and that these engines could be reversed 75 times in a minute. Now, what have we at Blochairn Works? A pair of engines of the same size, but with ample fly-wheel momentum driving two mills, which have turned out as much as 68 tons per shift, and on an average regularly turn out 56 tons. Of course, Mr. Ramsbottom's engines were being merely played with when the 75 reversals per minute were obtained, the cranks being jerked backwards and forwards through perhaps a quarter of a revolution. I have watched similar engines at actual work, and the reversing did not appear to me to be accomplished with any noticeable rapidity. It is easy to see that in such engines the pistons must be followed up by full-pressure steam to the termination of every stroke, and until the last inch of iron has been forced from between the rolls, whereupon, and quick as thought, the engines bound forward with the empty mill, until backward steam is thrown in the faces of the pistons to bring the engines

up, and reverse the motion for the next pass of iron. And with this there is a chattering of the spur gear enough to make one apprehend the tearing out of every tooth. Mr. Head applied the epithet "unmechanical" to the claw-clutch at the London meeting, and surely the same good taste must hold these reversing engines equally deserving of it. It is, of course, not so much a question of mere taste, but of greater efficiency, durability, and economy; and I affirm that these qualities cannot be combined in any arrangement which presents the jarring and irregular effects referred to.

I fully concur with Mr. Walker when, in the paper already referred to, he says—"The speed required is mainly limited by the power of the workmen to handle the iron in the rolls. The speed of the reversing mill should be as great as that where the iron is passed back over the top roll" in a continuously-going mill. The great practical question, therefore, for engineers and manufacturers is, to determine how this object may be most easily, safely, and satisfactorily attained. If we accept the results of extensive experience, we must dismiss the Ramsbottom system, with its fly-wheel-ignoring engines—the claw-clutch either by itself or with its various complications of cushions or slipping couplings; at all events, where employed in connection with mills over 20 in. diameter.

The Dowlais Works, as I have already indicated, have as good a claw-clutch as is to be found anywhere. They have also a pair of highly-finished engines of the Ramsbottom type; but with a lengthened experience of both kinds, Mr. Menelaus said, at the London meeting before referred to, that at that time there was no subject of greater importance to manufacturers of iron and steel than a good system of reversing rolls.

The strap arrangement, as tried at Blochairn, I affirm, has proved equally unsatisfactory; and yet it comprises a certain soundness in its principle, having failed simply from not being applied in a proper manner. The misapplied principle is that of the frictional clutch, exemplified in his arrangement by a strap and drum. These and the connecting parts introduced at Blochairn Works, have been altered again and again at intervals of from one to three weeks, and occasioned daily interruptions and stoppages. It is admitted, in the paper referred to, that when these mills were

erected, a little trouble was had with them; this "little trouble," however, having actually involved an expenditure for repairs and alterations nearly double the cost of the entire machinery. In explanation, Mr. Walker proceeds to say—"They made a wrought iron strap to go round the drum without any lining," and when they got into trouble with the strap "they lined it with wood, and in that way they got over the difficulty entirely." They, however, got over one difficulty only to get under another; the inequalities of the wood lining required that the drums should revolve more truly concentric; in consequence also of the rapid wear and inevitable varying of the configuration of the wood-lined strap, the springs intended to relieve it from the drum, on being disengaged, as also the other appurtenances, had to be re-adjusted almost every twelve hours. The paper conveys the impression that with a moderate amount of greasing and attention, the iron strap would not have given trouble by seizing on the cast-iron drum; but the fact is, that *half-hourly* rather than *daily* greasing had to be resorted to, and the consumption of grease amounted to £8 worth in a single week, besides the cost of application, and notwithstanding the iron strap wore down something like three-fourths of an inch in ten days. This iron strap was about 8 feet diameter by 12 inches broad, and had thus a bearing surface of 3,600 inches. Like all other frictional straps, however, those at Blochairn wore very unequally, in consequence of which only a limited proportion of the surface had the full pressure at one and the same time. This, I believe, accounts for the seizing referred to in the paper. This trouble of the strap seizing was, however, not by any means the most objectionable feature of the arrangement. It was no doubt bad enough both in itself and in pernicious consequences, but it was found in addition that the iron straps gripped so suddenly, and with such a wrench and shock to the machinery, as at times to be little if at all better than the old claw-clutch. The time elapsing from the moment the strap was brought into the slightest contact until the complete grip was too small to shock, and the actual engaging was quite sudden. It is true after the wood was employed, and when the straps were newly adjusted and lined up, the reversing was effected without noise; but they never remained in their adjusted state more than a day at a time. This characteristic of sudden gripping I believe to be that of other reversing

systems employing straps and drums, to which I have not yet specially referred. The frictional strap arrangement to which I have alluded, at the worst admitted of a slip taking place of perhaps 1-12th of a revolution, and with this amount of slip I have seen it wear away the wood lining, which was three inches thick, in less than 48 hours, and it seldom lasted out a week. The amount of slip named was utterly inadequate for softening the severity of the shock of starting the heavy rolls into motion, and was a degree better than those modifications of the claw-clutch I have already spoken of, with slip couplings, buffers, or springs. Notwithstanding that this strap and drum arrangement was tried at Blochairn in three different ways, it had eventually to be wholly abandoned after an outlay of an enormous expense in alterations Another faulty characteristic of the strap and drum arrangement is the self-gripping tendency of the strap, which is in truth not wholly inseparable from a friction-strap, even when worked without a differential lever; and this self-gripping action, in respect that it interferes with the due controlling and graduating of the engaging action, is perhaps as objectionable a feature as anything else in the entire arrangement.

The Napier clutch, which has just been minutely described to us by its inventor, is, in many respects, very similar to the arrangement tried at Blochairn. It consists of drums encircled by straps, tightened or relieved by differential levers, and steam or hydraulic power is dispensed with for putting the clutch into or out of contact. The strap is self-gripping, and after it has been allowed to touch the drum, my opinion is that it almost instantaneously assumes the driving-grip, its action between these points being absolutely uncontrolled and uncontrollable.

I ground these remarks alone on my observations of the action of this clutch in the reversing of planing machines, and the working of other light machinery, to which I think its application extremely suitable.

The amount of slip necessary on reversing a rolling mill must of course depend upon the speed of the mill, and on the diameter and number of pairs of rolls employed. In the case of a train of rolls consisting of two pairs of rolls, 26-in. diameter, making thirty-five revolutions per minute, I find the reversing is effected without the slightest noise or stroke by allowing a slip of three-fourths of a

revolution to take place from the first moment of contact of the frictional clutches until the mill is brought up to full speed, ready for receiving the iron between the rolls. This amount of slip, with a bearing surface of 42 superficial feet, and lubricated by water, wore a quarter of an inch in five months; and at this rate of wear, a set of segments will last two years, and then, at any time, they can be replaced in six hours.

However otherwise excellent any frictional arrangement may be for some purposes, it appears to me that if it cannot be brought into contact gradually and in a manner capable of adjustment and control, so that the degree of slip may be adapted to different requirements, or which cannot admit of some considerable jolting, which must at times result from the wear of the centre bushes, it is not a system calculated to meet the present want, or one capable of rendering reversing rolling mills sufficiently speedy, and at the same time smooth and safe in action. But even if friction straps can be employed at all in the reversing of heavy rolling mills (which at best is only problematical), it will become a question whether the deferential lever, by virtue of which mere manual energy is sufficient to actuate the frictional strap, but which admits of no variation in the gripping action, or the ordinary lever which involves the use of a steam or hydraulic engine, and which does admit of some slight modification, variation, or adjustment, when the gripping action commences, can best suit the desiderated purpose. It is my deliberate opinion, however, that a noiseless reversing action never can be permanently secured by the strap and drum arrangement, whether worked by hydraulic power or by levers of whatever kind; nor do I think it possible to obviate the evils of the varying configuration of a strap in working a large mill. The difference in the means employed in tightening the strap can never make any real difference in the action of the clutch itself, so far as rendering it durable and its action unvarying; and I think the experience at Blochairn goes to support this opinion conclusively. The friction stop being placed on a high-speed shaft, as proposed for the Parkhead Mills, will only have the effect of increasing the shock.

With regard to the application of the Napier clutch at the Butterley Iron Works, I must be permitted to say that in my opinion it affords little evidence in favour of its general adoption.

The mill being only 18 in. is of the lightest description requiring to be reversed, and is certainly not of the class out of which the requirement has of late arisen for a frictional reversing arrangement. The demand that has of late obtained for heavy plates and beams has rendered it imperatively necessary to erect the largest and most powerful mills for their manufacture, and the very size and costliness of such machinery makes it perilous to employ reversing systems, which are either beyond the control of the attendant, or are accompanied in working by sudden shocks or wrenches, and consequently annoying and disastrous breakages and interruptions; and no system can be said to meet this requirement till it is tried and proved on the mills out of which the necessity has arisen.

Having in the preceding review of existing arrangements shown that there is still a want in such machinery, I will now, with your permission, proceed to show in what manner I have myself endeavoured to supply it. I make no claim to the discovery of any important mechanical principle, for frictional clutches have been in use for years in various well known applications, and the conical clutch is probably the very oldest form of frictional clutch. It is, however, not only the oldest,—it is also the simplest and most efficient frictional clutch known wherever it is properly applied. It is therefore strange that its application to reversing rolling mills (which, more than any other machines, stand in need of its smooth and gradual action) should not much sooner have been worked out to a satisfactory result. About twelve years ago, it is true, an attempt was made to adapt it to this description of machinery by a French engineer, who seemed to be fully aware of its suitability for the purpose, but whose mode of arranging and combining the parts was so defective, disproportioned, and inappropriate, that it utterly failed in its purpose, and was wholly abandoned shortly after its introduction.

I first applied a cone-clutch to a rolling mill in 1869, at the Monkland Iron and Steel Works, under the employment and superintendence of Mr. Ferrie, the manager of those works. It was there the various trials were made which led to the construction of the cone-clutch. I now propose to describe these trials in connection with the gearing, on which the first claw-clutch ever used in Scotland, if not in the United Kingdom, had been originally

applied. That clutch was constructed in 1846, and, like many others of its kind, it occasioned breakages, and was soon abandoned; nor were any further attempts made to work the gearing with reversing motions until 1867—the recollections of that shocking clutch being until then too fresh to admit of another trial being made sooner of the reversing system, notwithstanding that the erection of a new mill of enlarged size had afforded a fair opportunity for it.

At Monkland, our faith in driving a rolling mill solely by friction was not then strong enough to inspire us with sufficient confidence to introduce such an untried innovation into the iron and steel works, and the first attempt on which we ventured was to combine a frictional clutch with a claw-clutch, the frictional clutch being designed to engage the mill, and to gradually bring it up to the required speed before the claw-clutch was brought into contact. Both clutches were worked by steam, but with separate connections, and two movements of the hand were required to complete the coupling of the compound clutch. This was soon noticed to be a source of difficulty, as the proper successive admissions of the steam required too great a nicety and accuracy of manipulation for practical purposes. The next attempt was to actuate both clutches by one admission of steam, with arrangements for one to act slightly in advance of the other, and this improvement promised well for a season; but the timing of the two motions in proper relation to each other could not be maintained for any length without continual re-adjustments of the connections between the two clutches. After various other attempts, which I need not waste your time by describing, the conviction was forced upon us that the combined clutch system was too complicated and uncertain in its action to give satisfaction, and must, therefore, be abandoned. After constant efforts, study, and experiment for a great length of time, it was ultimately resolved to try the single conical clutch by itself, and without its old claw companion, for in the course of our experiments we had found that with a suitable contact pressure the cones were quite capable of transmitting the power required to drive the large mill under all circumstances. Accordingly, towards the close of last year we proceeded to arrange and adapt the cones, that had formerly been employed conjointly with others, to work by themselves; but even in this we found

there was something still to learn. The cones, which in our occasional trials propelled the mill freely, were found to accumulate a small quantity of fine dust when worked continuously for any length of time, and this dust had the effect of causing a diminution and variation of the amount of friction and driving power, which became so serious through the course of a day's work as to involve a stoppage of the machinery and cleaning of the surfaces. At this juncture, Mr. Ferrie proposed that a small jet of water should be made to play continuously between the surfaces. This not only had the effect of keeping the surfaces perfectly clean, but increased the amount of friction and driving power, and at length the trials resulted in the most complete success. We found that any size of iron for which the mill (with 26-inch rolls) was adapted could be rolled freely, that the mill could be reversed without shock or noise, and that bars which collared or strayed in their course through the rolls, and were thus likely to cause mischief if forced through, could be arrested or returned as the roller-man may desire, and all this with the utmost ease and quietness. At Monkland, however, I cannot as yet boast of the beauty and symmetry of the machine, and those specially interested in this subject should visit Blochairn instead of Monkland. The frequent alterations and patchings which took place there in course of our experiments could not be expected to result in anything approaching to good taste or the nice adjustment and disposal of the parts.

At Monkland, we simply got the machine to work well, which it has done for the past nine months, and we are leisurely preparing new parts to perfect the apparatus, and are fitting it with adjustable wearing segments, as at Blochairn, the want of which has been the source of great trouble.

Messrs. Hannay & Son, on hearing and satisfying themselves of the success attained at Monkland, immediately ordered a set of clutches on the conical principle, to take the place of one of those fitted to the mills at Blochairn by Messrs. Tannet, Walker, & Co. After this set had been fully tested in operation, renewed orders came in succession for three additional sets; so that at this moment all the plate mills at Blochairn are working on this principle. The old clutches have been entirely removed, and the new cones are working to the entire satisfaction of workmen and

managers—complete in design as in operation The first set of the cones has now been in operation for five months, working night and day, and the mill has frequently turned out 40 to 50 tons of finished plates per shift. The other two smaller mills turn out each about 28 tons per shift. The fourth mill has only been started the other day, and I cannot yet speak of its power; but I am sure it will not fall behind its neighbour of the same size.

Fig. 1 is a sectional plan, and fig. 2 an elevation of reversing clutches. The shaft (33) carries two spurr wheels (35 and 36), which, by means of well-known arrangements of gearing, are continuously driven in opposite directions. The wheels (35 and 36) are formed with hollow conical rims (37) to frictionally engage with convexly-coned parts (38) upon a duplex sliding piece (39) between them, and they are fixed on elongated bosses (40) carried on brass bushes (41) on the shaft, whilst collar pieces (42) are bolted on the shaft in halves to sustain the end thrust of the coupling action. The position of each brass bush (41) is assigned in such a way that the plane of the centre of gravity of the wheel (35 or 36) may be at the middle of its length, or as nearly so as possible, whereby a tendency of the wheels when running loose to wear the bushes conical will be avoided. For this purpose the bushes (41) are elongated at their inner ends; and to admit of such elongation, the clutch piece (39) is made bell-shaped, as shown. The convexly-coned parts (38) of the clutch piece (39) are made in separate segments, fixed and adjusted by screw bolts, and on wear taking place they can be re-adjusted with the greatest facility. The conical surfaces are by preference made as shown, with a very acute inclination to the shaft, and the angle should in no case exceed half a right angle, for as a right angle (that of a plain disc) is approached, not only is a much greater pressure required to give the requisite bite, but the action of getting into contact is also more sudden and liable to produce injurious concussion. The duplex-clutch piece (39) is moved to put one or other of the wheels (35 or 36) into gear by a transverse-key of hammered cast-steel working in a slot cut through the shaft (33), and fixed in a rod or spindle (44). The spindle (44) is moved by means of a steam or hydraulic cylinder, but I prefer steam to hydraulic pressure, as the elasticity of the steam renders the engaging action both more gradual and the reversals more speedy. The contact pressure required is very little, and a very small-sized

steam cylinder working through levers as represented by fig. 3, is quite sufficient to give the requisite driving grip. A 12-in. steam cylinder is employed at Monkland, and at Blochairn the old water connections, formerly employed by Tannet, Walker, & Co., had to be taken advantage of in order to save further delays in getting the mills into a state fit for turning out iron to meet the great accumulation of orders caused by the previous interruptions, but I am gradually, as time will permit, substituting the water connections by steam reversing engines, as shown by fig. 3. This arrangement is also being constructed in connection with my reversing clutches to be erected at Gelsen Kirchen in Prussia, for Messrs. Grelo Fauk & Co.

In conclusion, I would remark that the difficulty opposing the successful adaptation of the frictional clutch cones to a reversing rolling mill, lies in the proportioning and modifying of the conical surfaces themselves, as well as the accessory details to render them practically applicable to the ponderous masses and gearing composing such machines. At the first glance one is apt to suppose that a conical clutch capable of transmitting the force of, say a 10 or 20 horses winding-engine, has only to be proportionally increased and extended in diameter, bearing surface, and pressure of contact, to at once render it suitable for driving a rolling mill requiring a 50 or 100 horses-power engine. However, a little reflection or, what is better, a little experience in the school of actual work, speedily dispels this illusion, and one becomes aware instead of its being a case for simple calculation, according to the arithmetical "rule of three," there is a somewhat deeper problem to be solved. A rolling mill is altogether so different from other machines in respect to the shocks and strains to which it is subjected, and a reversing rolling mill has so many stoppages, startings, and reversings, that arrangements and proportions have to be devised quite different from those prevailing in the ordinary applications of the cone-clutch, and it is to the devising of these that I have applied myself; and as you will have an opportunity (which I hope you will avail yourselves of) of seeing my conical reversing clutches for rolling mills in actual operation at Blochairn or Monkland, you will be able to judge how far I have succeeded.

I think it right, before resuming my seat, to refer to an incident which occurred in connection with the clutches at Blochairn, which

I am given to understand has been employed in several instances to create a prejudice towards them. About a fortnight after the first set of gearing was started to work, the transverse key 43 broke, and in its breakage slightly destroyed the key-way through the shaft and sliding-clutch. To have straightened out the key-way and fitted a new key of increased strength, would have involved a stoppage of work for two or three shifts; but as the mill was engaged on a very pressing order of plates, it was resolved to carry it on at all hazards till the end of the week, although it was seen that the chafed key-way would lead to the breakage of any number of keys. The changing of a key, however, only occupied about half an hour, and we managed to get them to last about a shift each, so that we used up six or seven of them before the week end, when an opportuuity was afforded for the hole being dressed out, and a permanent key put in, which has given no further trouble. The breaking of this key was due originally to the employment of a cast-iron distance-piece which goes between the two wheels and keeps them in their proper positions. This piece is loose on the shaft, and admitted of the key bending slightly backwards and forwards, which ultimately resulted in its breakage. In all the other sets of gearing, this distance-piece is forged on the shafts, which relieves the key from any tendency to bending or breaking. Altogether, this was a very small matter, and the only excuse I have for troubling you with it is the fact that it is represented to me that it has been exaggerated; and thinking it might probably be mentioned to members of this Institute, I deem it better to allude to the matter, so as to neutralise any misapprehension.

The description of performances with the Napier clutch at Butterley, to which we have just listened, appear to me to be pretty satisfactory, considering that they have been accomplished with a strap-clutch. It must not be forgotten, however, that the power required for every revolution of an 18-in. mill rolling a 6-in. round bar is barely $\frac{1}{8}$-th of that required to roll a plate 6 ft. broad and $\frac{3}{8}$-ths thick, with a 26-in. mill; and it remains to be seen whether this clutch can be so increased and multiplied in power as to suit it for mills of 26-in. diameter. So far as I have been able to form an opinion of the working of the Napier clutch, I am disposed to think its mere driving power can be multiplied indefinitely, but the

difficulty consists not in obtaining the necessary amount of slip to completely obviate the shock of engaging the mill, and this slip I am inclined to believe can never be obtained by the Napier clutch or by any strap arrangement whatever, nor do I think it possible to obviate the varying configuration.

The President said they had now before them two very important papers in relation to the driving of rolling mills and reversing gear. Perhaps there was no part of the rolling mill system at the present moment so important to the manufacturer as the thorough settling of that question, and, he thought, there was no question, in relation to the rolling mill machinery of the country, on which there were so many diverse opinions as to the best mode of accomplishing that apparently very mechanical question. With the number of facts they then had before them, they would be well able to form their own opinions, and on many points some of them would, no doubt, offer remarks to the meeting that would be of considerable importance. The first paper which they had had the pleasure of listening to upon the subject had been that of Mr. Napier, and, perhaps, they could gain some practical information upon the working of it if Sir John Alleyne would kindly give them some information as to what had been done by him, and after that, he (the President), believed that Mr. Kitson would also be able to give them some practical details of the working done on the second system described in the paper to which they had last listened, and then, he thought, the information gained from those two sources would prove to be of considerable importance.

Sir J. Alleyne said that as the president had put both papers before the meeting together, it would be impossible to discuss the question without making a very serious comparison between the two—the one against the other—and he trusted that such comparison would be taken by the readers of both papers in good part. When they came before a meeting of that kind they must expect no mercy, and must be prepared for the fullest possible discussion and criticism, and if anything should arise in the course of the discussion of an unpleasant nature, they must lay the blame on their worthy chairman for putting the two things before them for discussion at one and the same time. Now, he (Sir John) had been alluded to by the writers of both papers. Mr. Stevenson's paper,

he must say, appeared to him to be a critique of all the things in connection with the subject that had taken place throughout the country, and he found fault with it for, amongst other things, criticising one machine which he was quite sure he had not seen, that was the machine of Messrs. Napier, at the Butterley Works, and he (Sir John) was, consequently, rather surprised at the remarks he had made about it. He would merely preface his remarks with that statement, hoping that Mr. Stevenson would not think it an unpleasant one; he thought that that gentleman ought at any rate to have looked at the clutch before criticising it so severely. Amongst other things, he had stated that it could not be adjusted, whereas he (Sir John) could say positively that it was capable of the nicest adjustment. Before he put it to the mill, he got twelve clutches from Messrs. Napier, of the plan to drive the ordinary shop machinery, working one way, and that which he had before him was an exact model of it. Mr. Napier, in his paper, had referred to him. It was quite true that he first saw the thing described on the "Queen of the Thames," which vessel had been built by Messrs. Napier and Sons. When he saw it, he took out his note-book and pencil and made a sketch of it, with a view of adapting it for a rolling mill. While he was looking at it, Mr. Napier came up to him and said, "I hope you admire my clutch." He told him that he thought that it was the very thing that was required as a clutch for driving a reversing rolling mill. There was a thing that would adjust itself, and the man in charge of it could do no mischief. Mr. Napier had not described that point in his paper. He (Sir John) thought it was the most valuable part belonging to the whole thing. That little lever (referring to drawing) which in that case was very small, though of course the principle of the clutch was the same, was used instead of the hydraulic press, and (he believed) three engines to work the press, a hollow shaft and cotter, friction cone pipes, hydraulic presses, accumulator, lever valves, and screws to tighten up the segments of the cones. He would ask them to look at the complication of such machinery as that of Mr. Stevenson's. There was not half of it shown on the drawing before them—there was not even a quarter, and he did not think he should exaggerate if he said that there was not a tenth part of the machinery shown that was required to work Mr. S.'s clutch. Look at the engines, the accumulator, the pipes

underground, the hydraulic press going round with the shafts to draw the thing into gear; in exchange for all that they had, in Mr. Napier's system, a simple lever, the principle of which was, that as one side of the lever was longer than the other, the long end drew in more of the strap than the short end would. Mr. Napier had not pointed out to them that as those two points approached the fulcrum so the jam increased, and they could adjust it with very great ease. At the Butterley Company's works it was so adjusted. The man had to hold it slightly in at the point to which he pointed on the drawing, and the moment he slacked—if he saw anything going wrong—the strap would slip. As now adjusted it had not holding power enough of its own. The man had to hold it in gear. If the proportion of the two ends of the lever were altered, so that the long end was brought nearer to the crank pin or fulcrum, it would hold of itself, in fact it would do so by the shaft without any drum of a larger diameter, and the only point that he had to regret in the adoption of that clutch was, that he had pressed Mr. Napier to put a three feet drum, instead of letting him put up one of smaller dimensions. When they first got it to work he thought the jamming power would be so great that they would have a difficulty in getting it out of gear, he therefore asked Mr. Napier to try and stop the mill while the bar was passing through, and he did it with the greatest ease. To the horror of Sir John he saw him put his arms in to throw it into gear, while the bar was sticking in the rolls, and when he, and those with him, saw that they at once got out of the way, thinking there was going to be a grand crash, and there was no time to speak to him to prevent it; instead of that, however, he threw it in, and, to everybody's astonishment, the clutch gave a little bit of a slip, and the thing was done without any damage whatever, and he thought that was the greatest possible success, and it was so arranged at their works at the present time. It has been at work for six months—in fact ever since Christmas, and the only things they had to change were the running pieces to hold the sliding part in gear, and that was simply a bit of cast iron, about as big as a man's hand, that had become necessary in consequence of putting the centres so far apart that the man had to hold it in, and he believed—and Mr. Napier also, he thought—that that was the safest way to have it, because the moment the man left go, it had not sufficient holding power,

consequently it slipped. Now, Mr. Stevenson had said that it was only a small mill of 18 inches in diameter. The mill was 22 inches in diameter, and ran 45 revolutions in a minute. They had at Butterley another mill 30 inches in diameter, with 4 pairs rolls in the train that went 35 revolutions a minute—it had a common claw clutch which had been working for four years without change, and in that there was a bang which was very disagreeable, and which he, as a mechanic, admitted ought to be got rid of, and he thought Mr. Napier had got rid of it in his machine, with the greatest possible success. There was another most excellent clutch of Mr. Weston's, which, he thought, Mr. Stevenson had missed altogether, although a paper upon it had been read before the Mechanical Engineers, and that was a clutch which, he thought, might be usefully introduced. In Mr. Stevenson's, there were the cones, which, when they wore—and they were bound to wear up to shoulders. It had also a quantity of water splashing about, and that produced a slipping action, and consequent weak. Now, in Mr. Napier's arrangement, there was a strap going round the drums, and as they and the drums wore out, the lever followed and acted in the most beautiful way that he ever saw. The result would be, that if much wear occurred, the lever would simply follow and find its proper place; it would, in fact, adapt itself to the drums. He would simply point out that they were further putting it to another mill—a large one of 30 inches in diameter—where the shock was infinitely greater, and in that case he did not think they would put a larger drum than 3ft. The only thing that they had any difficulty in was that, owing to the drum being so large in diameter, and the machine running so fast, it had a little tendency to heat—for that, he took all the blame. Mr. Napier wanted to make it smaller, but he did not believe in the thing having the power that he really found it had; and for the larger mill, he did not think he should put a larger drum than 3ft. in diameter—in fact, it would hold by the shaft itself.

Mr. Richards (Ebbw Vale) wholly and entirely disagreed with the remarks made by Mr. Stevenson on reversing rolling mills on Ramsbottom's plan. What he told them about the wear and tear of engines and the chattering of teeth existed only in his own imagination. The rolling mill at Ebbw Vale (which had been visited by the Iron and Steel Institute a couple of years ago) had

now been working for 18 months night and day, and they never had the least trouble with it. It was a 30-inch mill, the engine having a pair of 50-inch cylinders, 4ft. stroke, geared up 2 to 1 and they had been working, as he said, night and day making rails 50 or 60 feet long without the slightest hitch or trouble whatever. He merely stated this because Mr. Stevenson's remarks might lead them to believe, perhaps, that Mr. Ramsbottom's plan of reversing was a failure, but he could assure them it was nothing of the sort.

The President asked Mr. Kitson to be good enough to favour them with a few observations.

Mr. James Kitson had only to state, in answer to the President's call, that the plate mill reversing gear was working with hydraulic power, and was working satisfactorily at Monkbridge Iron Works. The system is not the plan introduced at Blochairn Iron Works by Mr. Walker, but is according to the patented arrangement of F. W. Kitson and P. Chalas. The plate mill at Monkbridge Iron Works is a 26-inch mill, which makes about 30 revolutions per minute, and it can be reversed about 24 times in a minute, which is far more than sufficient for plate rolling. The friction clutches are two discs, which are held in contact by hydraulic pressure, and there is no difficulty in keeping them in regular and efficient working order.

Mr. J. T. Smith said that a general impression prevailed that the Ramsbottom engines used an excessive quantity of steam, and he was sorry his friend from Ebbw Vale did not allude to that point. Many present were probably aware that at Barrow they were working a pair of Ramsbottom's engines to drive a 26-inch rail mill, and had lately fitted condensing apparatus to these engines, and found that the difference in the quantity of steam used for a given amount of work by these engines, as compared with the ordinary condensing beam engines at their other mills doing the same duty, was very little in excess. In all their mills they rolled a length of rail which cut up into two, and often three lengths of the ordinary American section, the latter necessarily requiring bars of over eighty feet in length. For the past three months this work had been done by the Ramsbottom engines with 35 lbs. pressure, whereas before the condensing apparatus was used it could not be done without from 45 to 50 lbs. of steam.

Mr. Daniel Adamson, Newton Moor, (Hyde), thought that gentle-

men who criticised very freely should not object if they were hit a little in return by the members of that Institution. He was sorry to hear that Mr. Stevenson's paper was a recapitulation of the presumed inferior parts of other clutches, rather than simply a description of his own apparatus, which was what they expected. It was desirable, in a question of this sort, to put it in the first instance upon a basis of the soundest principles, and whether they adopted Ramsbottom's direct reversing apparatus, or the frictional clutch surface or not, their object was to reverse the least possible weight in a given time. Whether the large cylinder engines, or the small cylinder engines differed more or less in the work done—was not a question for them to discuss at all, as some might work at a boiler pressure of 10 or 12 or 15 lbs. per square inch, and others at 140 to 150, but if engines under such different conditions of pressure of steam, &c., were to be compared, not only should the diameter of cylinders be considered, but the velocity of pistons also. It was useless to discuss this question when only the relative diameter of cylinders was given, as in Mr. Stevenson's paper. The frictional clutch, as last described, had the evil in it that whatever maximum work they put upon the rolls, the force to keep up the frictional clutch must be equal to the maximum work done by the rolls. Supposing it was 10 horse-power at one moment of time, and 500 at another, they must not relax the force upon the clutch, but put the whole steam on the reversing gear equal to 500 horse-power that had to be exceptionally performed. He submitted that the differential clutch was the most beautiful arrangement that had ever come before that or any other Institute, for the work done by it was exactly the registered work put upon itself by the resistance in the rolls, and it had the additional advantage that it was self-acting and self-contained—that it did not—and could not—put one fraction of strain upon the clutch gear unless the work to be done was on the rolls. The work on the clutch was just equal to the draw, and the strength exerted would be exactly equivalent. He maintained that the differential clutch was one of the most beautiful things that could be invented for this purpose. In others, where the friction by incline or cone surface was brought into use to drive rolls, they must necessarily have a strain upon the reversing gear equal to the maximum work performed in the rolls, and they must never be relaxed during the whole of the time. With Ramsbottom's

engines reversing might be—and was—economically done, and those gentlemen who had seen such reversing engines at work at Ebbw Vale Works, would be quite satisfied that there was no difficulty in it, and in his opinion the 2 to 1 spur gear worked magnificently. There was not a 32nd of an inch of play between the spur gear of the 10-inch pitch wheels, and there could not be much concussion force there, so that the reversing was very noiselessly performed, and the result in expenditure of power in collision action would be very small indeed. On the other hand, if the driver or reverser of the Ramsbottom engines was an inefficient hand, he might be wasting a great deal of steam by letting the engines run after the work had passed through the rolls, for they must remember that the engine did not use one atom of steam unless the resistance was in the rolls to compel its use, except such as to overcome the friction of the engines themselves, and he held that the Ramsbottom system and the Napier differential system which had just been put before them, combined the two right principles if they were to reverse with the least possible concussion and momentum, and at the same time have the least possible strain upon the reversing apparatus while the work was being done in the rolls.

Mr. Menelaus had paid considerable attention to the subject under discussion. He would say to Mr. Stevenson that his arrangement seemed to work extremely well, but his remarks would turn chiefly upon Mr. Stevenson's finding fault with everybody else who had worked in the same field as himself. He found fault with the Ramsbottom system to begin with, and condemned it thoroughly. Now, they had had a pair of Ramsbottom engines working at Dowlais for some years, and they were working extremely well. They were employed in cogging steel ingots, which was a very severe test, as they had to be renewed very frequently. The engines were cogging about a thousand tons of ingots a week, and giving very little trouble—he did not say that they gave no trouble, but it was very little indeed. He was sure that they would go for years without any serious expense in repairs. This Ramsbottom system, however, was not perfect, and he had been looking for something better, simply because he was not entirely satisfied with the machine, as it was beyond all question that it was wasteful of steam, whatever Mr. Smith's experience might be to the contrary. On the other hand, it had other advantages which almost

compensated for this imperfection. Then, Mr. Stevenson went on to condemn entirely Mr. Napier's plan, although it seemed that he had hardly seen it. Now, when he first saw Mr. Napier's plan, he was of opinion that it was one of the most beautiful mechanical arrangements that he had ever seen, and he was very hopeful of its success when applied to rolling mills, and when they were told by Sir John Alleyne—who had fairly worked it—that it was a success, he thought it was going too far to say that it was not likely to succeed. After hearing Sir John Alleyne's report he was of a different opinion. He was very sorry that the spirited gentlemen, Messrs. Hannay, had not put up one of Mr. Napier's machines, because they might then have seen the two rival systems at work. He had only to say further that he was very hopeful of Mr. Napier's system, and was very glad to hear Sir John Alleyne speak so hopefully of it, and if he himself had to put up reversing machinery, he would, with the experience now gained, certainly hesitate before he developed any system in preference to Messrs. Napier's plan. At the same time, he was bound to admit that Mr. Stevenson's method seemed to be working very well indeed, and doing all that could be expected of it.

The President said they had listened to a very animated discussion on the comparative merits of the two inventions, and however great might be the difference between them—the one over the other—in the minds of practical men, he was sure that they would agree with him, that they owed many thanks to any gentleman who would bring a practical paper before them. It was no part of his duty—nor would he detain them—to enter into any personal discussion as to the respective merits of those two inventions. He thought it would save much valuable time, and afford greater facility for the discussion of the matter by joining the two systems, and for that purpose he had put the two papers before the meeting at once. The result of that they had seen, and it was his duty now only to ask them to give a vote of thanks to each of the two gentlemen separately, and he would take them in the order of the papers. The vote of thanks having been accorded to Mr Napier, he (the President) would ask them to do the same thing to Mr. Stevenson, who had given them a great deal of information upon the subject, and whose paper had elicited many facts of which otherwise they would probably never have heard.

Mr. Graham Stevenson desired, before the closing of the discussion, to have an opportunity of replying to some of the remarks made upon his paper. He did not know whether he possessed a sufficiently good memory to bear in view all the faults that had been found with it, and he could only touch upon them as they came up in his mind; but should he omit anything of importance, he would like extremely well to be reminded of it. He might tell Sir John Alleyne, to begin with, that he had not, in the slightest degree, offended him in anything he had said, neither had any other gentleman. It had been a perfectly fair discussion, and his system was brought before them for their criticism, and he promised them that the harder they hit it, or the more severely they dealt with it, he would like them all the better. He thought that any system that would not stand the most thorough scrutiny was not fit to be employed in the hazardous duty of working a heavy rolling mill. Sir John Alleyne had told them that he had not seen the clutch at work at the Butterley mills. That was quite true, but he thought he had taken pretty good care in his paper to indicate that he had not seen the clutch at work there, and had explained that the remarks he had made were based to a great extent upon his observation of the Napier clutch, in connection with planing and other light machinery, for which he considered it was extremely well adapted; he would yield to no one in admiration of the beauty of the Napier clutch. He thought it was one of the most ingenious contrivances that he had ever seen; at the same time it was only a strap clutch, and similar to the straps that had been used at Blochairn, only it was tightened or relieved by a different means, but whether worked by differential levers or by hydraulic power, he believed that no strap arrangement could ever work satisfactorily in reversing heavy rolling mills. Sir John Alleyne had also stated that he had said the Napier clutch was not adjustable. He did not think he had said anything of the kind, because he had studied the clutch minutely, and knew quite well that it was adjustable, and, therefore, did not think it possible that he could have made such a mistake; what he did say was that it could not be graduated and adjusted in its gripping action. Then, Sir John made a good deal of to-do about the numerous working parts connected with his system. Now, he did not want to be dogmatic, but he was perfectly certain that he could allow

any engineer to examine the working parts of the two systems, and if there were not more in the Napier clutch than in his own—in fact, if it were not found, on such examination, that there were four working parts in the Napier clutch for every one in his own, then he would give up the point. Sir John next referred to the cone wearing against a shoulder, but he assured him that was a thing that could exist only in imagination—such a thing as a shoulder could not exist. He had had experience of nine months' working of the clutches, and if such a thing could have taken place they would have been against the shoulder long ago. The segments were made exactly of the same breadth as the concave cone which received them, and when the one surface wore past the other it simply wore into a recess or space, but it would be seen that the segments were made adjustable, so that when wear took place these segments were set out at right angles of the shaft, and in that way no wear could take place in a lateral direction at all, the cone being simply expanded to follow up this wear. Then continuing to examine Sir John Alleyne's remarks, he would say that the application of the Napier clutch which had been described at Butterley was as satisfactory as could be expected. There was, however, nothing remarkable in stopping the mill with iron between the rolls, and then starting it again without relieving the iron. All frictional clutches should accomplish that with perfect safety. He (Mr. S.) had made a mistake in mentioning the size of the rolls at Butterley as being 18 inches, and stood corrected by Sir John that they were 22 inches, and he begged to apologize for the mistake; but while doing so, he would say that even 22 inches was a very light mill, and was not adapted for the heavy class of work that was now required in the enlarged dimensions of many of our iron constructions. He thought, however, that (although the application in this instance was to a very light mill) it was very likely that the Napier clutch could be so multiplied and increased as to drive even the largest and heaviest of mills, and he did not think he had ever said anything to the contrary, because he was quite convinced that the clutch could be multiplied infinitely in power, and so as to drive any kind of machinery; but what he maintained was, that it could not be made to slip sufficiently, and that was the point at issue. As regarded driving power, they could not have a better driving medium than the

common crab-clutch; but the difficulty was to overcome the shock to the wheels, and that could only be effected by the amount of slip that could be allowed to take place before the mill was brought up to its speed. The construction of a frictional clutch should be such as not only to be adjustable to the amount of slip, but should be arranged in such a manner as to maintain its configuration under the wear that was involved in meeting this purpose; and he maintained that the Napier clutch could not be made to fulfil these conditions. One of the speakers had remarked that his clutch must have a specific amount of pressure upon it, which would be invariable whether they were rolling a plate requiring 5 tons pressure or 50 tons pressure. The same speaker also said that the Napier clutch was variable, and that the work done and the pressure were in conformity to each other, and that the pressure was not put on at all unless the work was being performed; but he (Mr. S.) would say that was a complete error. He knew it to be a fact, the more the Napier clutch was resisted the firmer it gripped, but that was quite a different thing from what the speaker indicated. In his paper he had said that he was obliged to adopt the hydraulic arrangement at Blochairn because it was already there, and his taking the use of it was therefore simply facilitating the starting of the mill; but he had again to say that he did not approve of the use of hydraulic pressure. He preferred to have the contact pressure produced by a steam engine, as shown on the drawing (Fig. 3); and by that means they could so graduate the pressure as to allow a bar or plate to slip as it was travelling through the rolls. If a light bar was in the roll, they could by this arrangement moderate the pressure to suit all circumstances, so that the cones would slip the exact amount required, whether that was $\frac{1}{2}$, $\frac{3}{4}$, or a whole revolution. But it was not absolutely necessary to vary the pressure to save breakage; all that was needed was to employ a pressure, the maximum of which would not exceed the breaking strain of the weakest part of the mill, and that condition was more than they could acquire with the other clutch referred to, because it was self-gripping, and therefore not adjustable, as to the degree of pressure required for different kinds of work a mill might be required to do. Then there had been considerable fault found with him for finding fault with everybody else; but he had to remind them that was most distinctly the object of his paper, and was,

indeed, what he came there to do, but when they could show him a better plan of arriving at the true value of things, or one that could be esteemed better than that of comparison, he would renounce fault-finding and adopt such a plan. He had not denounced his own plan, that was for them to do; and when they showed him a better system, he would denounce his own as readily as he had found fault with others. He thought the best way they could arrive at a correct conclusion as to the merits of any system was to take whatever explanations could be given, and whatever comparisons could be made with other systems, and endeavour to learn as much as possible by that means, because the gentlemen attending these meetings had not opportunities of examining and comparing thoroughly the various systems which were involved in such a discussion as the present; they could not, for example, go to Blochairn and spend perhaps a month there to watch the working of his clutches. In reference to Ramsbottom's engine and the remarks made upon it, he had to say, in reply to the gentleman who thought that its defects only existed in his (Mr. S's.) imagination, that gentleman had said it was quite immaterial what size of cylinders were employed for driving a mill, because unless the resistance was present, the steam would not be called into use, the steam in the cylinders, he believed, was always in a corresponding degree of pressure to the power required. He (Mr. S.) believed that, generally speaking, that was a true proportion, and, in fact his opinion was that the larger the cylinders were the more advantageous use could be made of the steam, but this rule did not apply without a fly-wheel or without some other equivalent means of carrying the engine from the dead points to the full power points of its stroke. Ramsbottom's engines could admit of no fly-wheels, and the cylinders were consequently filled up with unexpanded steam at every point of the stroke, and that meant nothing short of throwing away a very considerable amount of power. One of the material elements in working with steam economically, was to have sufficiency of momentum, and there were many engineers present who would support this statement, who had much better means of obtaining experience in the matter than could be got in connection with rolling mills.

Mr. R. D. Napier wished to make one observation with regard to Mr. Stevenson's remark, that he thought it impossible for a

clutch working in his (Mr. Napier's) way to be put into gear noiselessly and safely, but with Sir John Alleyne's leave he would ask Mr. Stevenson to go to Butterley, and if in the course of one week he could produce a single shock he would make him a present of the apparatus.

Mr. Stevenson would be glad to go to Butterley, but without doing so he could say that the straps tried at Blochairn were not materially different from the one in point, and these were tried in three different ways, and it was found that one and all of them created a shock in starting the mill, and all straps would do so, whatever was the means of tightening them. The tightening in Mr. Napier's system was effected by means of the differential lever, the others were tightened by hydraulic power, and he would ask what difference could the means of tightening make either in diminishing the shock or obviating the wear. His experience at Blochairn had, in his own mind, conclusively proved that if the requisite slip did take place a considerable amount of wear was the inevitable result. Straps had been tried there for a couple of years, and persisted in at an expense he would be afraid to name, and the result was that the desired object, viz., the starting of the mills smoothly, could not be accomplished by their use. That was what he had succeeded in doing with the cones, and it was that which he maintained no straps could ever accomplish.

Sir John Alleyne thanked Mr. Stevenson for the kind way in which he had taken his remarks, and was quite sure that he (Mr. Stevenson) was quite welcome to go to Butterley and see what their machines were doing. The meeting, however, would bear him out in saying that he asked them to compare the parts of the whole apparatus. Mr. Napier had got everything in his model on the table. Mr. Stevenson had many things underground which were not seen; also, three engines working the accumulator and he asked them to compare the whole with Mr. Napier's whole, not merely the pieces of the clutch itself, but the parts required by the apparatus under each system of reversing, and he pointed to a small lever and said that there they would see Mr. Napier's system. He would show all that to Mr. Stevenson if he would go to Butterley. He again thanked Mr. Stevenson for the manner in which he had taken his remarks, and was quite sure the more they met each other in that manner the more knowledge and

information they would gain, and he for one would be much obliged to anyone who contributed to the attainment of that result.

Mr. R. D. Napier referred to Mr. Stevenson's remark that the clutch would not work, but if he would take the trouble to go to Butterley he would see it for himself. Another remark he wished to make was that the friction wheels of the machines Mr. Stevenson had compared to his (Mr. Napier's) were 8 or 9 feet in diameter. The others were about a third of that size, although they did the same work, also the friction straps were from 2 to 3 inches thick, and in his opinion no comparison could be made between the two things.

The meeting was then adjourned until the following morning at 10·30.

THURSDAY, 8th August, 1872.

The President said that already, as they were aware, they had had to postpone one of the papers on the previous day until that morning—the paper of Mr. Rowan, on the iron shipbuilding trade of Scotland. They had also on the list a very interesting paper on safety lamps, by Mr. Irvine, of Glasgow. That gentleman had kindly, in anticipation of the reading of his paper, taken a great deal of trouble to prepare models and experiments in connection with it, so as to be able to illustrate the subject, and as unfortunately some of the remaining papers could not come before the meeting, owing to the want of time, they would appear in the Journal, but as Dr. Irvine's experiments could not thus appear, it had been thought advisable to allow his paper to take precedence, particularly as it would be a short one; he would, therefore, call upon Dr. Irvine to read his paper.

ON A NEW MINER'S SAFETY LAMP, FOR INDICATING BY SOUND THE PRESENCE OF EXPLOSIVE MIXTURES OF GAS AND AIR, BASED ON A NEW FORM OF SINGING FLAME.

By Dr. A. K. IRVINE, Glasgow.

(Abstract.)

When a mixture of any inflammable gas or vapour with air, in explosive proportions, passes through and is ignited on the surface of a disc of wire gauze of such mesh as to prevent the passage of flame, and a suitable tube or chimney is placed above, and surrounds, at its lower end, the disc, preventing admission to the chimney except through the wire gauze, a musical sound is produced, varying in pitch, &c., with the size of flame and dimensions of the chimney. In this, as in other flames singing in tubes, the sound is caused by the vibration of the flame determined or intensified by the current up the chimney, and communicated to the column of air or gaseous fluid within the chimney, whose length commands and times the rapidity of the vibrations, so as to produce a given note, just as the flutter of the air originating at the embouchure of an organ pipe is commanded by the length of the pipe.

The conditions under which this flame is produced differ considerably, however, from those of other singing flames. The hydrogen jet, for instance, is burned in an open tube, to which air is freely admitted at the lower end, and it is necessary that the tube enclosing the jet should be lowered more or less till the singing point is found.

In my singing flame, the tube is not open at the bottom, no admission takes place except through the wire gauze, and the note is produced when the flame is at the lower extremity of the tube or chimney.

These are the conditions which give to this flame its applicability to the purposes for which I employ it.

The fact of the combustion of an explosive compound on the surface of a material impervious to flame (viz., wire gauze, originally employed by Sir Humphrey Davy in the construction of safety lamps), suggested the possibility of employing this flame for the

purpose of giving warning by sound of the presence of an explosive atmosphere in mines, or elsewhere, by means of a lamp suitably constructed. Accordingly, I have had lamps made for giving light, which, while the atmoshere is not contaminated by fire-damp, or other inflammable gas, burn in the usual way, but, which, as soon as such a gas mixed with air in explosive proportions enters,it appeals to the ear by a loud musical sound, as well as to the eye by its effects on the appearance of the flame in the lamp—just as in the Davy.

In one form of the lamp, which is more particularly adapted for the use of the viewer, or wasteman of a mine, the air enters near the top of the lamp, obviating the necessity of turning the lamp on its side, as is frequently necessary with the Davy, when but a thin layer of fire-damp is floating at the ceiling of the mine.

In another form, the lamp is adapted to the use of the working miner, and a superior light is obtained by the use of paraffin oil.

In a third form, specially constructed with the object of being a warning apparatus as well as a stationery light, the sound is given forth when an atmosphere of gas and air under the explosive point enters it.

I have thought of a variety of applications of this singing flame besides to safety lamps, but I bring only one more to your notice at this time, viz., its use as a fog horn, which, on account of its portability, simplicity, and cheapness, might take the place of a costly apparatus, and would be highly suitable for railway junctions, or other situations of danger. We are not limited in this case as in that of the lamp to a small-sized apparatus, and, consequently, the sound given out is much louder.

All the above apparatus was made to sound during the reading of the paper, and a number of experiments bearing on the subject were carried out with much success.

The President said it was with great reluctance that he found it necessary to depart from the order in which papers had been set down on the programme, but he felt justified in doing so on that occasion, in order that an opportunity might be afforded for the reading of Dr. Irvine's paper, which had been so well illustrated, and which he feared might otherwise have been left over; but he was sure the members would feel with him that he had been quite

justified in adopting that course after what they had just listened to, and would pass a hearty vote of thanks to the author of the paper.

Mr. Heath would, with the permission of the chairman, support the vote of thanks to Dr. Irvine for the very valuable experiments he had just been showing to them. He himself, with other members in the room, had taken a great interest in that particular matter, and anything pertaining to the safety of the miner was to him far more interesting than any experiments that could be shown to him which would simply fill his pockets with money, or enable him to hear a discussion upon anything in the shape of mechanics; and before he left Glasgow he should take an opportunity of asking that gentleman to bring the matter forward more publicly, either by the delivery of a lecture, or in any other way that was most pleasant to himself. They understood that it was a new lamp, and certainly it was quite new to him. In seconding the vote of thanks, he should be most happy to make some arrangement with Dr. Irvine to prepare a lecture or paper, if convenient to him so to do, in order to bring the thing before the public in the North Staffordshire district, because it was impossible to have anything, in a mining point of view, brought before practical miners that they would receive with greater satisfaction.

Dr. Irvine begged to say that he was very much obliged to them for the very handsome manner in which they had received him, and so far as he could he should be happy at any time to put himself at the disposal of anyone in order to show the lamp. He also begged to mention that he had taken out a patent for it a year ago, and so far as he knew this application of the sounding flame was entirely original.

THE RISE AND PROGRESS OF IRON SHIPBUILDING ON THE CLYDE.

By Mr. D. Rowan, Glasgow.

Commercial, iron built, steam-propelled ships, are those which are more particularly the subject of this paper. It is not intended to enter minutely into the history of shipbuilding, into the application of the steam engine for the propulsion of ships, nor a comparison of the merits of paddles *versus* screws, nor yet into the forms,

dimensions, or modes of construction with the multiplicity of detail of iron ships. This being a meeting of the Iron and Steel Institute, all that is intended is simply to illustrate from recorded data, the progress in quantity of this gigantic industry, which forms the principal market for the products of the manufacture of the members of this Institute.

As in a biographical sketch, however, it is necessary to place on record the particulars of youth as well as maturity—the former not unfrequently being the most delightful—so my paper would look somewhat barren, were I able only to state in detail that so many tons of steel and iron had been used in given periods of time in the construction of ships and machinery. I shall therefore, very briefly, give some details as to the methods which have been used, and the dates when applied for propelling ships by other means than sails or oars.

The employment of paddle wheels for the propulsion of vessels is of very ancient date, It is said the boats by which the Roman army, under Claudius, was transported into Sicily, were propelled by wheels moved by oxen, and in many old military treatises the substitution of wheels for oars is mentioned. For nearly three centuries before the improved steam engine of Watt, we find the most advanced mechanical genius of the times scheming in the direction of the application of some motive power to the propulsion of ships, not only by paddle-wheels but by submerged propellers. James Watt's patent of 1769, by which he claims the using of the steam above, as well as below the piston, is the practical solution of this great problem, and by which the steam engine is rendered capable of being successfully applied to propel vessels. This great improvement was used in the first practical steamboat, and to the present time we have not been able to devise anything better.

I need only mention the first practical application of the steam engine to the propulsion of ships at Dalswinton Loch, by Messrs. Millar, Symington, & Taylor, in the years 1787 and 1788, which led to the "Charlotte Dundas," on the Forth and Clyde Canal in 1802, the engine of which was as perfect an application as those of the present day, being horizontal and direct acting, and in every respect successful. In March of that year she towed two vessels, each of 70 tons burden, named the "Active" and "Euphemia," from Lock No. 16 to Port Dundas, Glasgow, a distance of 19½

miles, in six hours, being at the rate of $3\frac{1}{4}$ miles, although it blew so strong a gale right a-head during the whole day that no other vessel on the canal attempted to move to windward. This was followed, in 1807, by Fulton's steamer, the "Clermont," a vessel 130 feet long by $16\frac{1}{2}$ feet by 7 feet, having a boiler 20 feet long, 7 feet high, and 8 feet broad, with an engine, the cylinder of which was 24 inches diameter and 4 feet stroke, the paddle-wheels being 15 feet diameter, with floats 4 feet long by 2 feet broad. She could steam 110 miles in twenty-four hours.

The really commercial introduction of steam navigation in Europe was due to Mr. Henry Bell, of Helensburgh, who, on the 18th January, 1812, completed the "Comet," a vessel 40 feet long and $10\frac{1}{2}$ feet broad, propelled by an engine estimated at three horse-power, with two paddle-wheels at each side. This vessel sailed from Glasgow for Greenock every Tuesday, Thursday, and Saturday, and from Greenock for Glasgow every Monday, Wednesday, and Friday, in the morning, to suit the tide. The fares were 4s. and 3s. The vessel was built by Messrs. John Wood & Co., Port-Glasgow, and attained a speed of $7\frac{1}{2}$ miles per hour. There have been many claimants to the honour of having been the first to introduce the submerged or screw-propeller. In 1752, Daniel Bernouilli received a prize from the Academy of Sciences for an essay on the best manner of impelling vessels without wind. His proposal, which is very fully described in "Woodcroft's Sketch of Steam Navigation," was to use inclined planes moved circularly like the sails of the wind-mill. Bramah, in 1785, patented a submerged propeller, the description of which is precisely similar to that of Bernouilli. William Littleton patented a screw-propeller of three blades, in 1794. Edward Shorten also patented a screw-propeller in 1800, and tried it in 1802; and early in this century, Mr. Wilson, of Dunbar, now of Patricroft, made a series of most successful experiments with a screw-propeller, in a small boat worked by hand, in 1828.

Mr. Wilson, in 1860, issued a small treatise on the "Screw Propeller, who invented it?" from which it appears that the screw propeller was a subject of thought with him from the year 1808, having lost his father in 1810, who, after making two successful attempts in rescuing the crew off the wreck of the "Pallis," lost his life in the third attempt. This event rendered it necessary for

Wilson to support himself, and it was not until 1821 and 1825 that he was able to construct a model boat worked by clock-work. In April, of 1828, he had machinery applied to a 25-feet boat, and with two men to work it, in presence of a committee of the Highland Society, the speed attained was 10 miles per hour, and entirely successful. In 1832, the subject was brought before the Scottish Society of Arts, when the silver medal was awarded to him, value £5. In 1832, Sir John Sinclair introduced the subject of Wilson's experiments to the Duke of Richmond. In the same year the subject was reported upon by the officers in the Woolwich Yard.

Mr. Kincaid, of Greenock, was also an early experimenter with the submerged propeller. Observing the vanes of the windmill put in motion by the force of the wind, the idea occurred to him that by reversing the action in still air or water, and communicating the motion to the vane wheel, it would necessarily be forced inwards; and from this, as a starting point, he commenced a series of experiments, extending from 1828 to 1831.

His early experiments were made by affixing a shaft to the keel of a ship's boat, with three propellers at regular distances. The best result, however, was obtained by using only one propeller, placed at the after-end of the boat; which the experiments of 1831, with improved machinery, multiple gear, and the application of a fly-wheel, fully illustrated.

We are indebted to Captain Ericsson for the first complete screw steamer; in accordance with his patent of 1836, he built a model boat, and then in 1837, the "Francis B. Ogden," a vessel 40 feet long, 8 feet broad, and 3 feet draught, with two screws, each 5 feet 3 inches in diameter. So successful was this vessel, that at the very first a speed of ten miles per hour was obtained; and in towing a schooner of 140 tons, a rate of speed of seven miles per hour; and on the 28th May, 1837, the American packet ship "Toronto," under the command of Captain Griswold, was towed in the river Thames, at a rate of over five English miles per hour, by this miniature screw steamer. On Monday, the 14th October, 1839, the first experimental trip of the "Archimedes" was made. She was a vessel 125 feet long, by 21 feet 10 inches by 13 feet hold, mean draught 9½ feet, with engines of 80 horse-power. Her mean speed was 9·6 miles.

Many circumstances combine to make shipbuilding the most indigenous of British mechanical arts. Our insular position renders all communication with other countries dependent on this art. Our convenience, our foreign trade and commerce, our self-interest, and our self-defence, alike make it desirable that progress should be made and pre-eminence maintained.

Within the past 50 years, iron has become the chief material in shipbuilding; besides its inherent fitness, it is, from our abounding mineral wealth, in complete accord with our native facilities of production. The steam engine, also, as the great instrument of power, is from the same prolific source—our coal and ironstone mines.

The requirements of our sea-girt isle, and the abundance of our mineral resources, have given a natural inclination towards those mechanical pursuits in which we have up to the present time held a pre-eminence over all other countries.

To illustrate the progress which has been made in this locality in the great arts of shipbuilding and marine engineering, I am of opinion it will serve the purpose of the present meeting better that I illustrate our condition at periodic times, rather than go into details of the successive improvements which have, from time to time, been effected, or the individual firms which have been instrumental in carrying them out. The introduction of iron as a material in the construction of ships was first made with canal boats.* A sea-going steam vessel was made by the Horsley Company, of Staffordshire, in 1820; and in 1825 another vessel by the same company, to ply on the River Shannon.

On the Clyde, the first steamer built of iron was the "Aglaia," of 30 tons, in 1827, which plied on Loch Eck *en route* to Inverary. The first iron steamer which plied on the Clyde was the "Fairy Queen," of 39 tons, built in 1831. This vessel was constructed at the Old Basin, a mile and half from the Broomielaw, and launched into the Clyde. It was propelled by an oscillating engine, being, I believe, the first application of the oscillating engine to marine purposes.

The first iron screw steamer built and fitted out at Glasgow, was the "Fire Queen," in 1845, of 135 tons, and of 80-horse power.

* See proceedings of Scottish Shipbuilders' Association. Mr. Gilchrist on Early Iron Shipbuilding.

The first steamer which plied between Glasgow and New York was the "City of Glasgow," built of iron in 1850, of 1,609 tons.

The "Royal Sovereign," of 447 tons, built in 1839, was the first paddle steamer of iron that plied between Glasgow and Liverpool. Of sailing vessels the yacht "Cyclops," launched in 1836, was built of iron up to the water lines, and was well-known to the members of the Royal Navy Club. The "Iron Duke," of 393 tons, rigged, built in 1840, sailed from Glasgow to India. The "Glasgow," an iron sailing vessel of 100 tons, schooner-rigged, built in 1842, plied between Glasgow and Rotterdam *v.* the Forth and Clyde Canal.

I have been particular in giving extracts of the births of so many infants of an entirely new species, due to our natural selection of the most fitting materials, and I will endeavour to show that the whole range of Darwinian philosophy does not present an illustration of such rapid development, of such gigantic progeny, nor attended with such marvellous results, for by our new species the entire social and material condition of civilised, and I may add, uncivilised, nations have been altered and improved. As an amusing illustration of our day of small things in shipping, I give the arrivals of vessels at the Broomielaw, for the month of July, 1787, of which there were 22 in all, as follows :—

6	vessels of	2	tons each	... ...	=	12 tons.
5	„	10	„	... ...	=	50 „
4	„	15	„	... ...	=	60 „
2	„	18	„	... ...	=	36 „
1	„	25	„	... ...	=	25 „
1	„	30	„	... ...	=	30 „
3	„	35	„	... ...	=	105 „
22						318

The revenue of the Clyde Trust for river and harbour dues was £1,975, while for 1871, it amounted to the large sum of £164,188. The Customs revenue collected at Glasgow for the year I refer to (viz. 1787) was £370, while for the past ten years it has averaged over a million for each year. From the year 1812 to 1822 inclu-

sive, there were built on the Clyde forty-eight steamers, the hulls of wood. Of these the "Dumbarton Castle," of 81 tons, 32 horse-power, built in 1815, was the first to attempt to extend the trip to Rothesay. The trip was successful, and considered so extraordinary a feat, that the captain (James Johnston) was presented with an elegantly polished, painted, and gilt punch-bowl, in commemoration of the event. The "Britannia," 73 tons, 28 horse-power, built 1815, made a pleasure excursion to the Giant's Causeway and Londonderry, which at the time was considered a great risk; but being successful, led to the trade with Londonderry. The "Rob Roy," built by Mr. D. Napier in 1818, of 56 tons, 30 horse-power, was the first sea-going steamer in Europe. It was at once put on the station between Glasgow and Belfast, and proved very successful. Cabin fare, exclusive of steward's fee, 21s.

I will now close my remarks by giving some tables illustrative of the progress of shipbuilding on the Clyde, from the excellent statistical report of our City Chamberlain, Mr. West Watson; and to begin with, will give the number and tonnage of ships owned in Glasgow at decennial periods, and stretching so far back as 1810.

			With Tonnage of
In 1810, the number of ships owned in Glasgow was	 24	... =	1,956
„ 1820, „ „ „	... 77	... =	6,131
„ 1830, „ „ „	... 217	... =	39,432
„ 1841, „ „ „	... 431	... =	95,062
„ 1851, „ „ „	... 508	... =	145,684
„ 1861, „ „ „	... 679	... =	218,684
„ 1871, „ „ „	... 895	... =	433,016

Within the past sixty years the property in ships owned in Glasgow has multiplied nearly 222 times in tonnage, and fully 37 times in the number of ships. The following tables show the number and tonnage of the vessels launched during the past year, and also those in process of construction or contracted for at 31st December 1871.

VESSELS LAUNCHED.

	No.		Tons.
Iron steamers under 100 tons each	31	=	1,588
„ „ „ 100 „ to 500 tons	59	=	17,464
„ „ „ 500 „ to 1,000 „	22	=	16,444
„ „ „ 1,000 „ to 2,000 „	41	=	57,776
„ „ „ 2,000 „ to 3,000 „	19	=	55,508
„ „ „ 3,000 „ and upwards	11	=	38,692
Bessemer steel, P.S.	2	=	170
Wood steamers	2	=	30
Sailing vessels of iron	13	=	8,557
Total	200	=	196,229

Vessels in process of construction and contracted for, viz.:—

	No.		Tons.
Iron steamers	171	=	289,245
Sailing ships	9	=	11,311
Composite steamers	1	=	263
Wooden sailing ships	1	=	90
Iron dredgers	3	=	900
Total	185	=	301,809

That it may not be assumed from the preceding two tables, which form a record of the ships launched, under process of construction, or contracted for during and at the end of 1871—this being an exceptionally busy year and may not afford a just estimate of the average or ordinary produce of the Clyde district in shipbuilding,—I give a table of the work done and also the amount of tonnage under construction and contracted for at the end of each year from 1863 to 1871 inclusive.

	Tonnage launched.	Under Contract and on Stocks.
In 1863 ...	124,000 ...	140,000
„ 1864 ...	178,505 ...	105,957
„ 1865 ...	153,932 ...	109,404
„ 1866 ...	124,513 ...	71,869
„ 1867 ...	108,024 ...	124,082
„ 1868 ...	169,571 ...	134,818
„ 1869 ...	192,310 ...	140,999
„ 1870 ...	180,401 ...	180,175
„ 1871 ...	196,229 ...	301,809

Although the subject of my paper as given in the programme, is the "Rise and Progress of the Iron Shipbuilding Trade in Scotland," I have confined my remarks to what has been done in the Clyde district. For although this branch of industry has been prosecuted with equal vigour and success in Dundee, Aberdeen, Leith, and in some parts along the Fifeshire coast, as my time in which to prepare this paper has been very restricted, I have not been able to collect statistical reports from those places of sufficient accuracy to lay before this meeting.

The President would ask the meeting for a vote of thanks, which he was sure they would cordially give to Mr. Rowan, for the very interesting historical account he had given of the rise and progress of the "Iron Steam Shipbuilding Trade of Scotland." The vote of thanks having been carried, the President called upon Mr. Loüth to read his paper.

LOÜTH'S PATENT THREE-HIGH PLATE AND SHEET ROLLS.

By Mr. B. L. LOÜTH, Pittsburgh, U.S.A.

The plate mills erected in Great Britain, together with the sheet mills, are of two classes,—firstly, the reverse mill, wherein the whole train is reversed by means of clutch-gearing; and secondly, the ordinary geared mill which pulls over. To those who have had experience in the reversible plate mill, it is only too well known that the objections which can be urged against such a system are, firstly, the multiplicity of wheels (there being no less than five spur wheels requisite for reversing); secondly, the great cost in foundations and machinery; and thirdly, the liability there is to breakage. The shock upon the various parts of the engine caused by throwing a heavy train into gear is very serious, and leads to great cost in repairs, and is altogether a most objectionable form in which to run heavy machinery. If any means can be devised whereby this expensive and unsatisfactory mode of rolling plates can be superseded, it well deserves the attention of practical iron manufacturers.

Of course, the object of reversing is to save the labour of pulling a heavy pile or plate over the rolls, and in effect to turn out a larger quantity of plates in a given time as compared with the pulling over system. And to attain this object, as has been observed before, the clumsy system of reversing a heavy train is resorted to.

In the United States of America, nearly all the mills, whether for puddled bars, rails, or plates, are three-high; and the writer is not alone in his opinion that the system of three-high rolling for any class of iron that is required, is the one best adapted both for turning out quantity in a given time, and for lessening breakages by easing the strain upon all portions of the machinery, and also by lessening the labour of the men.

The means by which rails are rolled in the United States are by three-high rolling. The middle roll in the newer arrangements is fixed, and the top and bottom rolls move towards or from the middle roll by means of double screws, one at the top of the standard, and the other at the bottom of the standard, these screws being coupled so that the top and bottom will move simultaneously; and it is difficult to understand how any system of rail-rolling by means of two-high rolls can compare with the system I have described.

Now, with regard to plates and sheets. In the United States there are about twenty-three mills running three-high, and the character of these mills is as follows. The hard rolls are of the usual size, but between them there is a roll of smaller diameter; thus for a 4-feet roll by 20 inches diameter, the small roll would be 13 inches diameter; and for a roll 6 feet long by 22 inches diameter, the middle roll would be 16 inches diameter. As will be observed, on reference to the drawing, the bottom roll only is driven for the hard rolls, both the middle and top rolls running by friction. The rolls are all turned perfectly straight and level, so that they bear all over; and a stream of water is constantly kept on each roll to keep it perfectly cool. The effect of this is that there is no expansion and contraction of the rolls, and the sheet or plate is rolled to a perfect level, free from all buckling. The surface of the sheet or plate is very smooth, the water having the effect of washing off all the scale, and preventing it sticking to the rolls. Some people are under the impression that by using so much water the sheets and plates would get too cold. Such, however, is not the case, as the water runs off in globular form; and in

practice it is no impediment. By the old system of rolling, the plates and sheets are usually thicker in the middle than at the edges. By this system they are rolled all over to a uniform gauge, in consequence of the rolls being kept cold.

The reducing power of the middle roll is very marked, and this is accounted for by reason of the smaller area which is covered in the grip of the plate, in consequence of the diameter of the roll being smaller. The effect is, that a larger draft can be put upon the plate or sheet than by the old system with the same power involved in the machinery. It is a well-known fact that the smaller the rolls are in diameter, the easier it is to reduce iron. Again, there is the less liability to break in a hard roll by this system, as the bottom and top rolls are alternately strengthened by means of the middle roll. Another advantage of this system is, that the rolls with water on them will grind themselves to a true bearing all over in a very short space of time, and will do to a certain extent what is done in the lathe, and much better.

In the works of Messrs. Lyons, Shorb & Co., of Pittsburg, Pa., there is a plate mill erected on this system, the soft rolls being 30 inches diameter, and 9 feet long, two-high, with an overhead steam lift for bringing the slab up to the top of the roll. The finishing rolls are as described here. It is no uncommon thing for them to make thirty tons in twelve hours of finished saleable plates, some being as long as forty feet, and some as wide as seven feet.

Graff, Bennett & Co., of the same place, are now erecting a plate mill of gigantic proportions on this plan; but in place of the roughing rolls being two-high, the system of three-high is carried also, the same differential roll being there as in the finishing rolls. Of course, the soft rolls are driven by pinions in the usual manner, and the top roll is balanced as shown on drawing. The middle roll is also balanced with an apparatus, as shown on drawing, for moving it up or down by hand-gearing. It is expected that this mill will enable Messrs. Graff, Bennett & Co. to turn out between thirty and forty tons of sheared plates in twelve hours. With regard to what is done in this country, I am sorry to say that I have found prejudice run so strong amongst the English manufacturers, that I have been utterly unable to make headway until quite recently. Mr. Jones, of the firm of Jones Brothers & Co., the Ayrton Rolling Mills, Middlesbrough, has erected a set of these

rolls for sheets, and is about to convert his plate mill in the same manner. And many gentlemen are now beginning to be more alive to what may be done by this system in plate and sheet rolling, steel rolling for saws, and other purposes. Tin-sheet cold rolling, and copper and brass rolling, are peculiarly open to this improvement. The effect of rolling steel and tin sheets is very marked, giving them a finer skin and more perfect finish.

I have been indebted to Mr. Jones for the assistance he has given to me, and I hereby beg to thank him most cordially for that assistance. He has had the advantage of having seen a number of these mills at work in America, and at his own place at Middlesbrough, he has now had practical experience of them. If we were to take, for example, sheets, say six feet by three feet by sixteen wire gauge, it would be considered a good make in a sheet mill to turn out between seven and ten tons in twelve hours by the ordinary system. I believe Mr. Jones can tell you, if he is here, that there is no difficulty in working four furnaces in place of two to this mill, and turning out from 15 to 20 tons of the wire gauge sheets in twelve hours. I am well aware that this may be considered an extravagant statement on my part, but time will judge whether I have exceeded in my statements what can be done by this system.

The ease by which the men work, and the freedom from a heated roll, is much appreciated by them. There is no labour involved beyond pushing the piece in between the rolls, and the energies of the men are not exhausted by the severe labour which prevails at present.

The President said: The paper they had just listened to was one of great practical importance to those connected with the rolling of sheets. There were many gentlemen present who were so thoroughly acquainted with all the details of that manufacture, that he was sure if there were any questions they would like to ask Mr. Loüth upon the subject of his paper, so as to elicit further information, that gentleman would be very glad to answer them.

Mr. Menelaus wished to say a word or two on the rolling of iron rails. Mr. Loüth, had told them—and they were all much obliged to him for the information—that it was the custom in America

to roll with three-high rolls. It, however, would not be convenient in England to roll with three-high rolls, for several reasons,—the first of which was, that it would entail upon them the necessity of keeping a much larger stock of rolls than they now had; and it was well known that a considerable element of expense in making iron rails was the immense stock of rolls that English manufacturers had to keep to suit the tastes and opinions of engineers. In England they had three sections of rail—the double-head, the common flange, and the bridge rail; and every engineer who adopted the double-headed rail had his own form, and it was the same with those who used the flange and the bridge rails. The effect was that a great number of sections were in use in England, and when they added to that their foreign trade, the number of rolls became something enormous. At Dowlais they had about an acre of them, and he certainly should not like to have an acre and a half. That was perhaps the principal reason why they had not adopted the three-high rolls system for rolling rails. This multiplicity of sections made the orders for each comparatively small, and, consequently, they had very often to change the rolls. In one mill, sometimes they had to change rolls perhaps five or six times in the course of a week, and he need not tell them that it was very much easier to change a pair of rolls than to change three, and, as the changing of three rolls would take a considerable amount of time, it was easily seen that their adoption would tend to lessen the make except when orders were large. But there was another reason: English engineers were very particular as to correct section, and when they worked for foreigners—except the Americans—they found that they also were very particular as to section. Now, in America, where they had comparatively very few sections, and where, as he understood, they got large orders, and could so go on for perhaps a month rolling the same section, that objection did not apply. Except in very extreme cases, there was nothing of that sort in England. Rolls had often to be changed to preserve a correct section, and partly because the orders were small, whereas in America great nicety of section was not insisted on, and they had large quantities of one section to make at the same time, which enable them to run their rolls for long periods without changing. English manufacturers were not blind to the advantage of three-high rolls, but, taking into account the greater stock of rolls they would

have to keep, and the longer time that would be occupied in changing them, owing to the necessity of producing accurate sections for the satisfaction of English engineers, they had come to the conclusion that it was better to continue the plan of two-high rolls than to adopt the three-high rolls system for rolling rails.

Mr. Snelus only wished to say that he, in company with Mr. Jones, had seen the three-high rolls system at work in America, and could testify to its answering extremely well for the purpose to which it was applied. They had visited the works where the three-high rolls were in use, and they were extremely pleased not only with the cleanness of the plate, but with the evenness and parallelism of the two surfaces; there did not appear to be any hitch whatever, and the work was done with very great ease. Having seen the thing at work in America, he thought perhaps it would be interesting to the members to know how it succeeded, so far as he and Mr. Jones saw its application.

Mr. Danks was familiar with the system of rolling rails with three-high trains in America, and as Mr. Menelaus had made some remarks about sections which were very appropriate —he might say that he had been making rails for the last 24 years, and therefore, if he did not know anything about it, he ought to. For ten years of that time, he had used the three-high train, and he must confess that he was such a perfect convert to it that it would be very hard to convert him to another system; but, in regard to their engineers not being so particular about the section, he would confess that makers did sometimes let the rolls run a little longer than they ought to without dressing them, but if Mr. Menelaus wanted to test the fact as to whether the engineers in America were, or were not, particular about the section, he had better try and sell them a few rails of imperfect section.

Mr. Menelaus would ask Mr. Snelus, who knew what they were doing in England and America, what was his experience on that particular point. He had been in a great many rail mills in America, and, therefore, he would ask him to state the result of his experience. He himself had not seen the American mills, but he had heard many practical men who had been in America say that they were surprised to see the very bad sections—as they in England would call them—which were turned out there. He did not say that at all disrespectfully, as he knew that American ironmakers

could produce sections as good as any made in England, but the fact appeared to be that the American engineers did accept what we should call rails of bad section, and, therefore, the makers naturally contented themselves with working to suit their customers —and he would do the same if placed in a similar position.

Mr. Snelus could only say that Mr. Jones and himself had paid particular attention to the point in question when they were in America, and on many occasions they examined the rails to see whether the sections on both sides of the central line were perfectly the same, and in all instances they thought they could detect a difference with the eye only. When they came to measure it they found that the difference was unmistakable, and in all those cases the result was due to the bottom roll being fixed and the two top rolls being movable. He did not see any mill where the middle roll was fixed, as described by the gentleman who had read the paper, but he did see one very fine mill being built at Bethlehem, by Mr. John Fritz, and in that the middle roll was to be fixed, and then the section on each side the mid-central line would be the same. He (Mr. Snelus) had noticed the same facts in a recent trip through Germany, and where the bottom roll was a fixture and the two top rolls movable the sections were not true, but some mills were working there in which the middle roll was fixed and the top and bottom rolls were movable, and in those cases the sections were just as good as those of ordinary English rails.

Mr. Edward Williams had been rail-making for about thirty years, and had had almost all sorts of difficulties and troubles, but he never knew a difficulty as to the section of American rails. He thought this spoke very much for the practical good sense of the American engineers, who did not care to get the needless accuracy sometimes insisted upon by foreigners fresh from the technical schools of France and Germany—even by English engineers sometimes. With the best kind of two-high mill, it was sometimes next to impossible to please those who wanted great exactitude, and he was of opinion that it would not be possible with a three-high mill, especially if the bottom roll were the fixed one. There were, too, with three-high mills, difficulties that practical rail-makers would readily understand—upside-down guides, &c.—which could be surmounted; but he felt sure that, for making iron rails of usual sections and lengths, the old two-high mill was best. The smaller

stock of rolls was itself a great advantage, and only one skilled roller was necessary, whereas the three-high mill must have two. Iron rails could not be rolled very long, because they must be finished at a high heat; but Mr. Bessemer had shown how to make a metal that would roll at almost any heat, and the probability was that we should roll very long lengths, to save crops, and cut up to the lengths required afterwards. When they came to make Bessemer metal as cheaply as they were now making iron—and he thought the day would come when they would do so—the two-high rolls would disappear altogether. He (Mr. W.) was inclined to think that when that time came, they would have four-roll mills —two rolls going in one direction, and two in the other—in effect, two old-fashioned rail mills so placed as regards each other that the rolling in one direction would be the exact equivalent of the rolling in the other direction. With regard to sheets and plates, he thought the system then spoken of ought to succeed. Having seen it working at Newport, he felt bound to say that it seemed to him to do very well, and he was disposed to think, that for such work as making sheets to cut up into nail strips, the system would do very well, and he heartily wished it success; but he could not quite see the *rationale* of that which was said about the surface of the sheet being better, and he thought that that was a mistake. There was upon the surface of iron a kind of nap, which, if continually smoothed in one direction, would lie pretty well, but to keep rubbing it backward and forward would be pretty much like brushing a hat both ways, and if any one would try that for half an hour he would find that it did not improve the surface. If they wanted a smooth surface they must, in his opinion, continue to roll in the same direction, and not backward and forward. Then, as regards the water, he could not see why water should not come on two-high rolls, as well as on the three, and if it would do for the three, it would certainly do for the two.

Mr. Danks did not wish to prolong the discussion about rolling rails, but he would refer to one remark that had been made about fixing the centre rolls. He maintained that there was a way of fixing them in the three-high rolls, so as to produce iron in as good a form, and of as good a section, as in the two-high rolls, but they might fix them as fast as they pleased, yet they would not stay fixed, because the bearings would wear.

Mr. Jeremiah Head said that although he had not seen the central roll system at work, he was satisfied that it would prove of great value to plate makers. Mr. Loüth had attributed the difficulty he had met with in introducing his invention to prejudice. He submitted that this accusation was scarcely merited, as it was quite impossible to take up at once all the numerous systems which were offered to their notice. Yesterday, for example, they had discussed two new expedients for reversing rolling mills, and it was well known there were three or four more, almost any of which were better than the ordinary clutch system. An inventor's mind was naturally occupied with the idea that his invention was superior to the appliances in general use, and he was apt to lose patience when he found manufacturers unwilling to act as he desired. But these latter had other things to take into account, viz., which of all competing plans was the best, and that being determined, whether the present was the best time for effecting the change. Valuable plant must, if possible, be made to repay its own cost, and the greatest caution was necessary before deciding to supersede by a novelty any machine which was doing its work fairly well.

Mr. Farnworth, referring to the three-high rolls, was very pleased to hear rails mentioned, also single sheets, but no one had spoken about rolling doubles or tin-plates with the three-high rolls. He would like to ask Mr. Loüth whether in America they had adopted that system for any gauges thinner than the 16 gauge, and if so, how they had overcome the difficulty of the open end without its being reversed. They all knew that in rolling doubled sheets the closed end is passed through first, this appears especially requisite on thin gauges, to prevent a pinch or buckle on the sheet, and in tin plates too. If they could overcome that, and still have the same surface from water as hot chill, then the American point was achieved. They all knew that where water was used it always produced a rougher surface on the roll than when the roll was allowed to run hot and without water. All tin-plate makers, for instance, found that by putting the water to run on their cold rolls they always got a rougher surface than the plate had before the water was put on and it was also well known that water in consequence of its abrading tendency is used for the purpose of getting a perfectly plain cylindrical surface on such rolls, and that after the water was

taken off they had to adopt other means of getting it up to a high polish before rolling again, and if Mr. Loüth could enlighten them upon that subject, he should feel very much indebted to him.

Mr. Loüth said, that they were doing it at Middlesbrough at the present time—doubling sheets. Acting upon the old saying that the proof of the pudding was the tasting of it, all that gentlemen had to do was to go there and see it, as he was sure Mr. Jones would be pleased to show them the operation.

Mr. Farnworth asked how thin the plates were.

Mr. Loüth replied that they were up to No. 20.

Mr. E. Williams remarked that that was putting two sheets, one on the other. Mr. Farnworth meant such as No. 27 and 28 gauges.

Mr. Loüth said it had not been done. They had never made over a No. 22 gauge, but for cold rolling tin they had got the thing in operation at M. De Wendel's works, in France. There they had been working with it for a long time. Mr. Head was mistaken if he thought that he (Mr. Loüth) had been here only a few months. He had been trying for pretty nearly ten years to introduce his invention, and was happy to say that he was now getting along very well, and for that he was very thankful. Mr. Williams wished to know why they could not use water for the two-high rolls as well as three. The reason was that he (Mr. Loüth) finished the plate so much quicker than Mr. Williams did, that he did not give it a chance to get cold. In Mr. Jones' works, the other day, he had in ten minutes made one ton of No. 16 sheets, and that was pretty quick work. He (Mr. Loüth) would be pleased to show any gentleman the process, if he would only go down and see it, as he believed that would do more good in five minutes by seeing it at work than a week's talk about it.

The President was very glad to find that Mr. Loüth's paper had called forth several interesting remarks from practical men on this very important question. He would not detain the meeting with any remarks upon it himself further than to refer to one thing his friend, Mr. Menelaus, had done. He had shown in a few words how exceedingly desirable it was that he should get out of the difficulty of a continuous change in the size of rails. One would have really thought that English engineers must by this time have arrived at something like a given section that would answer the purpose on one line of rail as well as on another. By

adhering to minute distinctions in the size of their sections they (the engineers) were entailing heavy cost and great inconvenience on the lines they represented, and there could be no practical advantage whatever to the companies by pursuing that course. On the contrary, there was an immense increase in the cost of production, as well as great annoyance to the manufacturers. On a former occasion he had had the pleasure, when speaking to the members of the Iron and Steel Institute, of expressing a wish that a universal system of rails should be introduced in this country, where, by taking perhaps three sizes—a small rail, a medium rail, and a large rail—the whole of the traffic would be accommodated, and he hoped that the remarks which Mr. Menelaus had made upon that subject would make an impression, for they evidently showed that the companies and manufacturers were still labouring under a great difficulty, although it was one which might be easily removed. With reference to the paper their American friend had read to them, it had elicited a good deal of practical detail which would be useful, and he was sure that they would give him a vote of thanks for it.

The vote of thanks having been awarded, Mr. Spencer then read his paper :—

FURTHER IMPROVEMENTS IN SPENCER'S REVOLVING PUDDLING MACHINE.

By Mr. A. Spencer, West Hartlepool.

In the paper read at the London meeting in March last, I intimated that a machine on my principle was being constructed to puddle one ton of iron per heat. This machine, and the improvements effected in it, I now beg to bring before this meeting. As it is somewhat incomplete in its details, and with its powers of production scarcely developed, I should not have presumed to occupy your time, had not several of my friends, members of this Institute, expressed a desire that I should let them know how the machine was getting on.

I propose to describe its general construction, method of fettling it, the working of it, and the tools employed generally; afterwards to enlarge on those points which are novel in it.

Description of the Machine (*see Drawing A*).—The grate is of the ordinary shape and construction, but in size proportionate

to the capacity of the revolving chamber. The bridge is a common water-bridge, marked (1), open to the top and bolted on the end plate (2) of furnace. The bridge neck (3) has a flange or ring upon it, for the double purpose of confining the brickwork immediately above the bridge, and for supporting a loose ring (4), which serves to form a close joint between the fire-grate and the revolving chamber.

The revolving chamber is a long square box, as in the machine I formerly described, but longer,—the internal dimensions being when fettled, 9 ft. 6 in. by 4 ft. 8 in. In the present machine all the sides are parallel to the axis of rotation, the advantages of this being that each side can be fettled with the molten cinder, so as to have a perfectly level surface, and of an even thickness throughout. The sides are composed of open trays or girders of cast iron (*see Drawing B*), placed transversely instead of longitudinally as in the former one, in order to resist the torsion when revolving. As in the former machine, it is supported at each end by a cast iron disc; and on account of its greater size, there is also in the middle of its length a third disc or ring as an additional support. These three discs which carry the chamber revolve on large rollers fixed in a strong frame and bed-plate beneath the machine.

At the flue end (*Drawing C*) of the chamber a moveable neck (6) is placed, made of wrought iron, lined with fire-bricks, which forms the junction with the chimney (7), provided at the lower end with a cast iron mouth-piece (8) in halves; suitable guides; and means of lifting.

The chimney (7) is of the ordinary type, having a wrought iron mouth-piece (9) on its side, corresponding with that of the sliding-neck, and is supported upon girders (10) and columns (11), made sufficiently strong with the intention ultimately of placing a boiler to utilise the waste heat.

THE METHOD OF FETTLING (*Drawing A*).—The fettling, as before, is composed of "mill tap," or "mill tap" mixed with "pottery mine," "purple ore," "roll scale," or any other suitable oxide of iron, cast into the sides, and is built in blocks properly moulded, against the ends, the whole being cemented together by "molten tap" into one smooth and regular form; this may be called the structural lining. The repairing is done by means of wrought iron spouts (14) which convey the molten fettling

direct from the furnace, or ladle, to either end or sides as may be required, and occupies about three minutes.

THE MODE OF WORKING (*Drawing A*).—The charge of iron is melted in a cupola, and then carried by a ladle or by a spout to the flue-end (5) of the revolving chamber. In the moveable neck a small door (15) is opened, which admits a spout mounted on wheels, which reaches over the joint (16), and dips slightly so as to allow the iron to run freely, and lessen the height which it has to fall. Immediately the iron begins to flow the chamber is made to revolve slowly, thus preventing the iron eating into the bottom, and at the same time hastening its conversion. The charging of a ton of iron occupies about three minutes. When completed, the spout is withdrawn from the neck (6), the small door (15) closed, and the revolving of the chamber continued. The boil begins in about five minutes and continues from 10 to 15 minutes, the coming to nature, dropping, and balling occupies 10 or 15 minutes more. If several balls are required, the operation going on inside the chamber is observed very carefully through spy-holes in the neck, and when balls of a sufficient size are formed the machine is immediately stopped. Should the whole heat be wanted in one mass or ball, the chamber is allowed to continue revolving slowly, and the firing kept well up for about 10 minutes, when it will be found that one compact and well-formed ball is the result.

The withdrawing of the heat is effected by a pair of long tongs mounted on rollers, attached by a chain to a small hauling engine. The moveable neck is found to be a very compact and simple arrangement, as it may be raised or lowered just as easily as the door of the ordinary puddling furnace.

PARTICULAR POINTS OF IMPROVEMENT (*Drawings A, B, C, and D*).—I now return to the points of novelty in this machine. The first is the discs (17). It will be remembered that the discs of the machine described at the last meeting were each made of semicircles of cast iron strongly flanged and bolted together; but the expansion occasioned by the heat soon convinced me that bolts and bars were of little avail, and the discs, instead of remaining round, took a somewhat oval shape. This difficulty has been overcome in the present machine by making the end discs into two perfect rings (17 and 18), fitting loosely one within the other, with sufficient space between them to allow for expansion,—the inner ring or centre piece (18) of each

disc being kept in position by bolts passing through flanges provided for the purpose on both rings; it is also further strengthened by having strong hoops of wrought iron (19) contracted on it. As it is of similar size and shape to the inside of the chamber, it absorbs the greater part of the heat, and thus relieves the outer ring of undue strain through expansion.

The sides of the revolving chamber are made up of open trays (20) of cast iron of girder form, with wrought iron plates (21) rivetted on them, and held in position by bolts passing through them and through the discs, thus tying the whole together by wrought iron capable of allowing of any expansion without danger of breaking.

The next point is the moveable neck or flue, a very simple but effective improvement, and made to slide somewhat like a wedge between the aperture of the revolving chamber and the chimney. The wedge shape is given to it for the purpose of allowing it to recede from the face of the chamber when lifted, and free itself easily from any cinder which might otherwise clog the joint (16). Weighted levers give it the requisite pressure when the machine is in motion to keep the joint quite tight, without the use of wedges, screws, or luting, at the same time admitting it with the most perfect ease to serve the purpose of a door and screen, and may be opened, wholly or partially as may be necessary, when the heat is being drawn; but as it is most frequently required in such cases to be only partially opened, it still admits of the heat being carried to the chimney (7) or boiler, if there should be one applied to the furnace.

It will be noticed that I have in this machine dispensed with the diagonal throw which my former machine had. I have done this somewhat reluctantly to simplify the machine, and hitherto find the result satisfactory.

I now come to the arrangement for withdrawing the charge. Immediately on the neck being lifted, a frame upon wheels, and carrying a nicely balanced tongs, is advanced to the doorway and made to grip a ball; the whole is then steadily drawn back by means of a chain attached to the small hauling engine. This process is repeated until the chamber is discharged.

The charging ladle I have been unable to complete owing to pressure of other work. I therefore will not go into a description of it, being as yet an untried tool.

For the shift I saw the machine at work, $7\frac{1}{2}$ tons were turned out. By letter received this morning from works, I find that 9 tons 3 cwt. 3 qrs. 9 lbs. have been turned out in one shift of 12 hours.

The production is not yet at its highest; but I am confident by a little perseverance and practice with the tools and workmen, 100 tons per week will be puddled, and this, owing to the peculiar manner of fettling, may be continued for months in succession.

I am convinced that the increased size in the machine is a step in the right direction. I regret that on account of the difficulty of getting work done in these extraordinary times, I was unable to complete the machine some weeks sooner, which would have enabled me to lay before the meeting some trustworthy statistics of its performance, but the trials I have been able to make all promise great economy and success, and I believe the time is not far distant when we shall be able to make homogeneous iron rails of a character to compete successfully with steel.

When all is complete and in order, I shall be very glad to appoint a day when the Puddling Committee, or any member of the Institute, may see it at work, thus giving an opportunity to make your own observations and deductions, and I have no doubt you will be highly pleased with the enterprise and liberality of Messrs. Thomas Richardson and Sons, who have so willingly encouraged me in the experiments, at the sacrifice of so much time and money.

The President said that if any gentleman wished to ask any further questions of the author of the paper, he was sure that that gentleman would be very willing to enlarge upon any point, if it had not been already sufficiently considered and explained in the paper which he had read, otherwise he would ask the meeting to do what he was quite sure they would do with great pleasure—viz. —pass a vote of thanks for the very able paper Mr. Spencer had written upon the subject. They had only two more papers on the programme, one of which it would be their duty to take as read, and the other on the use of the revolving rabble in the double puddling furnace would, with the consent of the gentlemen representing that invention who was then present, stand over to their next meeting, when he was sure that the members would give that attention to it that he could hardly ask them to do on the present occasion.

The following resolutions were afterwards duly proposed, seconded, and unanimously passed :—

"That the Iron and Steel Institute, in General Meeting assembled, hereby tender their best thanks to the Lord Provost and to the civic authorities for the cordial reception they have given to the members on the occasion of their visiting Glasgow, and for placing at the disposal of the Institute, gratuitously, the elegant suite of rooms in which the meetings have been held."

"That the best thanks of the Iron and Steel Institute be given to the Council of the Philosophical Society, and to the Committee of the Royal Exchange, for the facilities they have afforded the members in connection with this meeting."

"That the members of the Iron and Steel Institute, in General Meeting assembled, desire to express their full appreciation of, and best thanks for the arrangements made by the Local Committee and by the Local Honorary Secretary, Mr. Burns, for the reception of the Society, and which have resulted in a highly successful and agreeable meeting."

Bailie Bain, on behalf of the Civic Authorities, said, that in the absence of the Lord Provost, of Glasgow, who, he was sure, very much regretted his inability to be present at that time, he begged to thank them, in the name of the Corporation, for the resolution which they had just passed to that body. He was sure it had given the Corporation very great pleasure indeed to place the rooms at their disposal, particularly so, considering that that institute numbered amongst its members the names of so many eminent men connected with a trade of an industrial character, in which that district was very largely interested

Mr. Menelaus proposed a vote of thanks to the Chairman for the very able manner in which he had conducted the business of the meeting.

Mr. Edward Williams begged to second the proposition, which was carried with acclamation.

The President said that it gave him very great pleasure to meet them in various parts of the Kingdom. As to his conduct in the chair, of which his friend, Mr. Menelaus, had very kindly spoken so favourably, he could only say that he was always willing to do his best, and only regretted that they had not a chairman who was more able to discharge the duties of the office in which they had placed him.

The business proceedings then terminated.

ON THE WESTWARD DEVELOPMENT OF THE IRON MANUFACTURE IN THE UNITED STATES.

By MR. T. GUILDFORD SMITH, PHILADELPHIA.

THE necessities of the Colonies in North America, at a very early date, compelled the inhabitants to begin the manufacture of iron. We accordingly find historical notices of furnaces whose very place is now forgotten, as well as the more enduring ruins of the stone stacks then in vogue. The fuel used at that time was, of course, charcoal, and the furnace was always located near to some iron deposit, wood for the charcoal being abundant everywhere.

But as the forests were gradually cut down, and charcoal became dear in the older settlements, the make of iron decreased, and the furnace itself was finally abandoned for a new one built in the vicinity of fresh woodlands. So the march of settlements have gradually thrust the manufacture of charcoal iron into the backwoods. Charcoal furnaces are now only to be found in the extreme north-west, as in Michigan; or in the south, south-west, as in Alabama and Tennessee, where great local deposits of iron ore exist.

The destruction of timber in America, which has been going on steadily ever since the first settlers landed, is at last attracting public notice, and it is hoped that before long, a system of inspection will be instituted in the several states, by which the cutting of trees will be limited by statute, and the balance restored by planting each year some approximation, at least, to the number cut down. It may not be out of place to say here, that California, one of the youngest states of the Union, has created the office of State Forester, and made an appointment to fill it. Propositions have also been made to the National Congress, for the planting of trees in the public dominion, but as yet they have not taken any definite shape.

As long as charcoal iron maintains its supremacy in the market for various purposes, the question of wood supply is not without interest to iron men, but its chief aid would be, of course, to supply the demand for timber of all kinds which has already risen in value at a rate but little dreamed of a few years ago. But the importance of this subject to iron men in America was much lessened in 1837, when our first experiments in smelting iron with raw anthracite coal were successful at Mauch Chunk, in th e Lehigh Valley, Pennsylvania

David Thomas, of Colasangua, was the first to make this application in the United States. Mr. Thomas had been brought up in Wales, and carried with him the germ of this application to his adopted country. He is still living, and the honored president of the American Society of Mining Engineers. Soon after, Mr. Thomas began his furnaces at Calasangua, on the Lehigh. From this discovery in 1837, we now have in this Lehigh region, alone, 38 furnaces, turning out 378,000 tons of iron, while three new furnaces are building of a total estimated capacity of 27,000 tons additional.

In 1840, when the making of iron in the Lehigh began, the product of the whole United States was only 285,000 tons; while to-day the make in the Lehigh region alone exceeds the make of the Union in 1840, and the total production in the country has reached nearly 2,000,000 tons in 1870.

When Mr. Thomas built his furnace in 1840, solitary and alone, he would have been thought visionary indeed had he predicted the valley as it now is, lined with collieries, blast furnaces, and rolling mills, from the head waters in the coal regions, to points further down, where it leaves the iron deposits.

In the Schuylkill Valley, Pennsylvania, and often on the Susquehanna, the anthracite pig iron trade gradually became firmly established, and thus it was that the three important outlets of the Pennsylvania anthracite coalfields became the cradles, so to speak of this great industry.

It must not, of course, be understood that this development went on without its ups and downs, for until the last decade the iron men of the United States had not, as a rule, been successful; nor, indeed, had the coal miners. These two industries are so intimately connected, that one can hardly be affected, and not the other.

These industries suffered from two causes: the first and most important was the vacillating policy of the various administrations of the Government with reference to free trade or protection, so that capital and skilled labour were kept waiting for something definite. Then, again, while the pig iron men might have perhaps lived a fitful life during these times, yet their customers, the manufacturers of rails and bars, were in a worse condition from the same causes, and reflected a similar want of stability.

So the iron manufacture in the United States got on but slowly for twenty years—say, until 1860.

In spite, however, of these obstacles, the industry took root, and is perhaps better able to bear its prosperity to-day from its schooling in adversity in years gone by.

Up to 1840 but little iron had been made except with charcoal, the immense deposits of bituminous coal with which coke is now made for iron smelting were as yet too far from markets, except in a small way, perhaps, at Pittsburg, or in Virginia or Maryland.

Eastern Pennsylvania, the first home of the iron trade, is drained by the Lehigh and Schuylkill rivers so far as the coalfields are concerned, both of which flow into the Delaware. The Susquehanna, a little further to the west, but still flowing into the Atlantic, was the next home of the iron industry; next the Juniata Valley; but it was not until the Alleghany Mountains were crossed that the manufacture of iron may have said to have fairly "gone west."

Pittsburg, "where manufactured iron and steel are more largely produced than in any other point in the United States," became the next seat of iron manufacture. This city is at the junction of the Alleghany and Monongahela rivers, whose waters reach the gulf of Mexico, by the Ohio and the Mississippi. The rise and progress of Pittsburg, named in honour of one ot England's greatest statesmen, is more like the history of your own Middlesbro', save that the position of Pittsburg, at the head of a large and navigable stream, gave it a prominence as an entrepôt for commerce before its "iron age." At Pittsburg, the manufacture of steel obtained its first permanent "lodgment" in the United States. To-day, the skill and enterprise of her people are engaged in establishing the manufacture of phosphor bronze, the new metallic alloy, which seems likely to rival steel in many of its uses.

The manufacture of iron stopped to breathe, if I may so express it, some time at Pittsburg. Before reaching there, coke had been substituted for anthracite coal as a fuel, and coke continues to be the principal fuel used at Pittsburg still. But not far from here, in Clanin County, Pennsylvania, and at Youngstown and Zanesville, Ohio, still further west, they discovered a coal, called block coal, which they could use in the raw state in their blast furnaces, and make an iron of superior quality. This gave a new impetus to what may be now called "western iron manufacture."

Thus far, at all the various halting places of the iron trade, local ores had been used mainly, but the time had now arrived when the

trade demanded the purest iron ores available, and were prepared to pay for their transport from a distance, hoping to be remunerated in the end by the superiority of the product obtained, which the use of the raw block coal with them was proven to secure.

Let us pause here for a moment to examine what this new fuel (block coal) is, and what are its peculiarities, for this coal is found to exist not only in this isolated district comparatively, but in a larger field in the State of Indiana, where its use is giving peculiar value to the iron made with it for making Bessemer steel.

Dr. Foster, of Chicago, says, in a pamphlet on "Mineral Wealth, and Railroad Development," page 17, that "the term 'block,' as descriptive of a peculiar class of coals, came in an unscientific way to the geological vocabulary, but it has now become so firmly rooted that it must hereafter be recognised as legitimate. The physical characters of this class of coals are these: there are two systems of joints traversing the seam perpendicularly, which cut the mass into quadrangular blocks, two or three feet long, and one foot or more broad, and the miner availing himself of these natural divisions, after having undermined the base, is able to pry out the blocks without resort to gunpowder. He can easily take down three tons a day. The sides of the block are smooth, of a dull bluish colour, and are often stained white with fire clay; but if cleft longitudinally, there is seen a mass of mineral charcoal, so slightly cemented by vitumen, that it readily cracks on handling. This coal, when thrown upon a fire, at once ignites with a crackling sound, and burns with a bright yellow flame. It is non-coking, or, in other words, does not run together, thus affording free air passages. It is so free from sulphur that it leaves behind a white or grey flocculent ash, and, subjected to the strongest drafts, it gives no clinker. From careful assays, it is ascertained that this class of coals gives from 57 to 62 per cent. of fixed carbon. These block coals, we know from experience, when tested in a blast furnace, have all the qualities of charcoal as a reducing agent. Two and a half tons are required to make a ton of iron. It is a significant fact that the puddled iron made at Indianapolis from block coal, pig is employed at Pittsburg in forging gun barrels."

From the above description of Dr. Foster, the importance of this discovery to the western manufacture of iron is not easily to

be over-estimated. Using this fuel, and some Lake Superior magnetic with some local ores, soon brought the furnaces at Zanesville, Ohio, into notice.

The demand for the Lake Superior, or iron ores so celebrated for their purity, began to increase soon after the discovery of this block coal.

With a view of forming an economical junction of block coal and Lake Superior iron ore, the iron trade took another step farther west, and located itself at Cleveland, on Lake Erie, where it is permanently established, and likely to go on increasing from year to year.

"The census of 1860 gave a total of 76 blast furnaces located in Ohio, Indiana, Michigan, Illinois, Wisconsin, and Kentucky, and 24 rail-bar, sheet, and boiler plate mills, with a capital of $3,370,000, employing 2,804 hands, at a cost of $1,094,160, and producing 85,723 tons, of which 40,000 were rails. In 1870, three works alone in these States have invested more than the capital of 1860, employ 2,800 hands, at a cost of $1,556,000 in wages, and produce 100,000 tons of rails, 90,000 tons of pig, and 10,000 tons of bar and plate iron."

The following figures of the production of iron ore and pig iron, from the Lake Superior district, speaks for itself. [*See A. P. Swineford's Report.*] In 1856, 7,000 tons of ore, no make of iron; value of the ore, 28,000 dols. In 1860, 116,908 tons ore, 5,600 tons pig iron; value both, 736,496 dols. In 1870, 856,471 tons of ore, 49,298 tons pig iron; value of the ore and iron, 6,300,170 dols. Or since 1856, the value of the total output of ore and iron is, 29,069,883 dols. In 1870, the product was from sixteen mines, and finds a market in all parts of the country. The largest portion of the ore is sent to Cleveland, Ohio, whence it is re-shipped to the coalfields of the Mohoming and Shenango valleys by railroad. "About one-hundred furnaces in Ohio and Pennsylvania use Lake Superior ore, while nearly all the charcoal furnaces in the North-west are supplied with it."

As we go next from Cleveland, following the progress of the pig iron manufacture, we find no important cities dependant on this branch of business for their growth until we reach St. Louis.

Neither Cincinnati nor Louisville have as yet become prominent as manufacturing cities, although it is likely they may do so before long, when railroads now building are completed.

The gap from Cleveland, Ohio, to St. Louis, Missouri, is almost destitute of ironworks, except those built and building on the newly discovered block coal of Indiana, and mainly within that State. This gap embraces two-thirds of the State of Ohio, the entire State of Indiana, and that also of Illinois. These three states, with Wisconsin and Michigan adjoining them on the north, have already over 1,700 miles of railway in operation, and many miles more in construction. The renewal of the lines alone, to say nothing of the new rails required for the new roads, and the demand from other states accessible by water transport, is the basis upon which new furnaces and rolling mills are being rapidly projected and built. Indianopolis, a railway centre of considerable importance, is already the home rolling mills, and a little further west, at Brazil, Indiana, where the block coal was first discovered, 1866, five blast furnaces are at work.

At Terre Haute, further west still, one blast furnace and a rail mill are in successful operation. These all have taken their rise since 1860, many as late as 1867.

This coalfield is destined to supply St. Louis, as well from the foundation of works within itself. At St. Louis, blast furnaces have been erected on the most extensive scale, and more are building, one of the finest rolling mills in America has been erected there, and from the splendid situation of the city, she is destined to take a most important part in the iron manufacture of the United States.

Over fifteen furnaces are in blast there, and several rolling mills. Its proximity to the Indiana coalfield and to the celebrated Iron Mountain of Missouri, makes it a cheap as well as convenient point of manufacture. In 1868, 105,000 tons of ore were taken out from Iron Mountain; in 1869, 195,000 tons; 1870, 316,000 tons and last year it was confidently expected to reach, if not exceed, 500,000 tons, from which it will be seen the iron trade is growing.

The manufacture of Bessemer steel has in like manner followed the same path as that trodden by the iron in its westward career. The first works, on the Hudson, at Troy, New York, then at Harrisburg, Pennsylvannia, in the valley of the Susquehanna, then at Lewistown, Pennsylvania, in the valley of the Juniata, at Cambria, County Johnstown, Pennsylvania, at Pittsburgh, Pa., Cleveland, Ohio, Wyandottee, Michigan, Iolict, Ill., and at

Chicago, and, finally, up to my latest knowledge, at Milwaukee, Wisconsin.

The iron interest follows close upon the tide of immigration. The charges for transportation for such long distances encourage the building of furnaces and rolling mills at the earliest practicable moment. Their erection mark very accurately the years in which wealth has been accumulated.

It will thus be seen, that from the Atlantic to the Mississippi, the iron men are fairly at work, extending north to the Canada line, and south to the southern part of Alabama. And for the present, until more extensive discoveries of coal are made west of the Mississippi, I think the progress of the iron further west is checked, and it will now follow the coal and iron deposits as they are developed north and south of the line which it has hitherto marked its native migration.

The total mileage of the railroads of the U.S. amounts to over 60,000 miles, and has increased in the last decade, at the rate of ten per cent. To supply this demand for rails, and to keep up the renewals of these roads, and to furnish other demands for iron, now keeps "700 blast furnaces, and 300 rolling mills at work, which employ 140,000 men directly in the business." In addition, we are indebted to foreign countries for 511,059 tons of rails, to say nothing of the vast amount of imports of other forms of iron and steel manufacture, amounting to 826,088 tons. This surprising demand for iron and steel is, it is believed, true of all civilised nations at this time, and accounts for the prevailing prosperity of the trade everywhere.

I cannot close this paper without alluding to the fostering care which the policy of many of the railways in America exercises upon the growth and prosperity of the iron trade.

One of these roads, the Philadelphia and Reading Railroad, upon whose line the Punier furnace was built, and which was in 1840 a small road with but few miles of track, has grown now to be a corporation of great wealth, owning and controlling in its great anthracite coal traffic 1,100 miles of track, over 100 miles of canal, 70,000 acres of the finest anthracite coal lands in Pennsylvania, and with an entire coal tonnage last year of 6,002,573 tons.

This great road now offers special inducements to parties building furnaces on the line of its road, by assistance with its credit,

which to the often too moderate capital of the American furnace builder, will go far in determining the location of his works. The other home of the anthracite pig iron trade has not been any less successful than its neighbour, and we find the coal traffic out of the Lehigh, Lackanana, and Nilkerbane regions last year to have been also very large, and the total anthracite put out in 1871 was 14,965,501 tons. [*See Miners' Journal Report.*]

The bituminous fields on the sea board have been also prosperous, and added together, make 4,451,959 tons for last year.

The western coalfields have not been idle, but their figures are not capable of such exact registration as those on the Atlantic sea board; but a careful estimate made by competent parties put the amount as 11,500,000 tons. [*See Miners' Journal Report.*]

If we now add together these various sums, and include 443,955 tons of bituminous coal imported, and 2,720,000 tons, the estimated consumption in the coal regions themselves, we will have as a grand total 53,811,664 tons as the total supply for home consumption in the United States for 1871. This may be said to be the measure of our manufacturing prosperity. [*Miners' Journal.*]

Following the example of the Reading Railroad, one of our western lines is offering to give in fee not only the land upon which to build a furnace, or a rolling mill, or a Bessemer steel works, but also 100 acres of coal land, upon which collieries can be cheaply and easily opened.

While acknowledging the mutual dependence of our railroads upon the iron trade, and *vice versa*, I would not omit to state the great influence which the introduction of the manufacture of Bessemer steel into America has had in creating a demand for the best qualities of pig iron; and in demanding of a furnace manager not only the greatest care in the manufacture, but also the exercise of all knowledge and skill in the selection of his ores and fuel.

I do not hesitate in saying that the introduction of this manufacture has done more to awaken inquiry into hitherto neglected resources, particularly of iron ore, and called out definite knowledge in respect to the peculiar values of different coals, than almost any other one incident in the history of the iron trade. Mr. Bessemer's name has become a household word in America, and I need hardly add, is hononred as much with us as with his own countrymen.

ON THE GENERATION OF HEAT DURING THE BESSEMER PROCESS.

By R. AKERMAN, Professor at the School of Mines at Stockholm.*

Experience has more and more confirmed, that having at hand proper materials for the Bessemer process, there is nothing which exercises so powerful an influence on the quality of the product as the degree of heat which is attained during the process. The greater this heat, the closer and more homogeneous will, as a rule, the Bessemer metal turn out; besides which the danger of its becoming red short is proportionately diminished. Nor does it seem improbable that the brittleness, which at times characterises Bessemer metal, stands in some relation to a deficiency of heat during the process. Lastly, a good heat will also produce a larger percentage of steel in ingots, partly because a less quantity of material is thrown out by the blast, in proportion as, by the raised temperature, the bath is rendered more liquid, and partly because the metal refined at a high temperature is sufficiently superheated not to cool in tapping, and thus to form scull. A correct insight into all the circumstances which, during the process in question, affect the degree of heat, must therefore be of the greatest importance to every Bessemer smelter,—the more so that the differences between the kinds of pig-iron employed in Bessemer steel making, which arise from the varying qualities of the ores, are sufficiently marked to require very different conditions in different places to attain the desired high temperature.

The wish to contribute, at least in some slight degree, to a dissemination of the knowledge, in these respects, which has hitherto been acquired, is the principal motive for the present memoir, which has, however, been more immediately called forth by two dissertations published in the course of last year, namely, Mr. Jordan's, in "Bulletin de la Société des Ingenieurs Civils," and Professor Kupelwieser's, in Oesterreichische Zeitshrift für Berg-und-Hütten-wesen," from which papers the substance more essentially bearing on Swedish production will be communicated in the following, conjointly with my own calculations and views.

* Translated from the Minutes of the Institution of Civil Engineers in Sweden, by C. P. Sandberg.

The object of conversion, as is well known, is to free the iron from the matters with which it is combined in the pig, and which principally consist of carbon (from 2 per cent. to 5 per cent.), silicon (0·1 to about 1·3 per cent. in Sweden, but from 0·3 up to 4 or 5 per cent. in coke pig-iron), and manganese (from traces to about 4 per cent., and in spiegel iron occasionally as much as 20 per cent.). The removal of these matters is brought about by their oxidation, which does not, however, take place quite simultaneously, for at the commencement it is, principally at least, the silicon and manganese, together with a small portion of iron, which are oxidised; while in ordinary cases most of the carbon is only removed after the greater part of the two first-mentioned substances has formed a slag.* The silicon and manganese remain even after oxidation, in contact with the iron, forming as silica and protoxide of manganese, together with the oxidised iron, slag; but the oxidised carbon, on the other hand, goes off partly as carbonic oxide, which afterwards, in contact with the air, is further oxidised into carbonic acid.

Conversion by smelting was, up to the year 1855, exclusively effected by the pig-iron—either in contact with charcoal, as in the hearth-forging, or separated from the fuel as in puddling—being smelted down and exposed to the oxidising influence of the air, as well as of the slag; and in this process no consideration whatever was attached to the generation and consumption of heat which was caused by the chemical reactions taking place in the smelted mass; but in order to obtain a sufficient degree of heat, the simple expedient was adopted of burning separate fuel. The heat engendered by the combustion of this fuel was, however, in by far the greater proportion, entirely lost, partly with the dispersing products of combustion, and partly by the outward radiation from the walls of the furnace; whilst only an inconsiderable portion was brought to act on the iron, partly by its contact with the flame, and partly by the heat communicated to the mass from the furnace walls. In order by this method to smelt down 2 tons of pig-iron in a puddling furnace, and heat it to about 1,400 degs. centigrade, a quantity of about 1 ton of coal was consumed, from which was

* See Calvert and Johnson's investigations of the puddling process, "Annals of the Iron Office, Stockholm, 1858, page 202," Kollberg on the Bessemer process, "Annals of the Iron Office, 1865, page 314," and Brusewitz on the same subject, "Annals of the Iron Office, Stockholm, 1871, page 222."

produced about 7,500,000 calories;* but of these, according to Jordan, 5,000,000 to 6,000,000 were carried away with the gases, and about 1,000,000 were lost by radiation from the furnace walls, while only about 600,000 calories, or say $\frac{1}{12}$ of the heat produced, were absorbed by the pig-iron bath. Now, as regards the fuel which is consumed in the puddling, as well as the charcoal-hearth process, after the pig-iron is smelted, the said fuel is not only entirely wasted by these processes, but a proportion of the heat produced by the oxidation of silicon, manganese, iron, and carbon, which takes place during these processes is, in point of fact, lost also. The correctness of this assertion will be best apprehended by a comparison with the Bessemer process, in which, with the exception of that possibly necessary for smelting down the pig-iron, no separate expenditure of fuel is required; but the heat generated by that process in itself is so well made use of, that the material or metal remains in a liquid state, and is consequently much more heated than during the puddling process, or process of refining in the hearth.

The Bessemer process consists, as is well known, in forcing atmospheric air through the molten mass of pig-iron; and the cause why the heat generated by this process is so much more completely utilised than in the other converting methods, is simply from the briskness with which the conversion takes place in the Bessemer converter, the whole mass being penetrated by compressed air, and the refining, or oxidation, being consequently effected simultaneously through the whole mass. This "intermolecular" combustion pervading the whole mass of iron, is also the cause of the walls of the Bessemer converter not becoming so superheated as would be the case if it were attempted to bring the mass up to a similar degree of temperature in a reverberatory furnace, because the walls of the Bessemer converter receive the heat, so to say, second-hand from the metal, whereas the contrary takes place in a reverberatory furnace, in which the metal is heated chiefly by the radiation from the roof and walls. It is clear, moreover, that the greater the mass which is manipulated at one time, and the more quickly the process is carried on, the less is the proportionate heat which the walls of a Bessemer conductor will have to absorb and conduct away, and the hotter, in consequence, will be the metal.

* A calorie = 3·968 British thermal units.

Following, principally, Mr. Jordan, we will now, in the first instance, endeavour to explain the conditions of heat which take place during the oxidation of the different substances which enter into the composition of pig-iron, as well with pure oxygen as with atmospheric air, and with so-called "dry" steam at a temperature of 100 degs. centigrade; but before doing this, it will first of all be necessary to put forward certain assumptions in respect of the condition of the pig-iron bath, &c.

According to Pouillet and Péclet, the melting temperature for white pig-iron rich in carbon, is 1,054 degs. C., and for grey pig-iron rich in graphite, 1,200 degs. C. According to L. Rinman, the smelting temperature for ordinary Swedish pig-iron stands at about 1,200 degs. C. Its height of liquefaction, by the same authority,* amounts to 46 calories and its specific heat

between 0 degs. C. and 200 degs. C. to 0·13
" 0 degs. C. and 1200 degs. C. to 0·16
and for molten pig-iron to 0·21

If, therefore, the initial temperature of the Bessemer pig-iron bath is assumed to be 1,400 degs. C., or 200 degs. higher than necessary for melting the pig-iron, it would for each ton of pig-iron possess

$$1000 \left\{ (1{,}200 \times 0{\cdot}16) \times 46 \times (200 \times 0{\cdot}21) \right\} = 280{,}000$$

calories; and to change its temperature 1 deg. C. would require the addition or subtraction of 210 calories for the same quantity.

It will be shown, further on in this memoir, that the whole of the oxygen contained in the current of gas injected for converting the pig-iron, is not always completely absorbed by that pig-iron, but that this only takes place under certain conditions; but inasmuch as it should always be the object to try to bring about a complete utilisation of the oxygen (because otherwise the metal will become less heated), we will in the following calculations uniformly assume that the oxygen has been fully utilised. It may further be presupposed that the gases passing off from the bath have, in ascending through the latter, absorbed so much heat that, in the main, they leave the bath with its initial temperature, or 1,400 degs. Finally, we will likewise assume that the walls of the converter are perfectly infusible, and that no heat is carried away through them from the bath. These assumptions certainly can never

* Survey of the Transactions of the Royal Academy of Sciences, 1865.

be fully realised, but no essential discrepancies need occur on account of them, inasmuch as this desideratum is approached nearer and nearer in proportion as larger quantities of pig-iron are converted at the same time, while the process, nevertheless, is accelerated.

In order to make the calculations as easily applicable as possible, they will throughout be made per ton of pig-iron.*

COMBUSTION OF IRON.

1. *With Oxygen.*—For the oxidation or combustion of 10 kilos. of iron, or 1 per cent. of the assumed quantity of pig iron, there will be required, $8:28=2{\cdot}857$ kilos. of oxygen, and the product is 12·857 kilos. of protoxide of iron, in the formation of $2{\cdot}857 \times 4{,}205\dagger = 12{,}013$ calories are produced.

The whole of this heat cannot, however, be utilised by the iron bath, partly because the protoxide which has been formed decreases the quantity of the metal, and partly because it has a higher specific heat than the metallic iron (0·17 instead of 0·11 in the solid, and probably still more in the molten state) on which account it must deprive the bath of at least

$$\{12{,}857 \times (0{\cdot}17 - 0{\cdot}11)\}\ 1{,}400 = 1{,}520$$

calories.

There remain consequently for the additional heating of the bath, per ton pig iron employed, $12{,}013 - 1{,}520 = 10{,}493$ calories for every per cent. of iron burnt with oxygen gas.

2. *With Atmospheric Air.*—For the combustion of 10 kilos. of iron will be required 2·857 kilos. of oxygen, which in the air is accompanied by $\frac{2{\cdot}857 \times 77}{23} = 9{\cdot}57$ kilos. of nitrogen. The quantity of heat generated in a ton of pig iron would, as in the previous case, amount to 10,493 calories, were it not that the nitrogen, in ascending through the bath, absorbs and carries away with it $9{\cdot}57 \times 0{\cdot}244 \times 1{,}400 = 3{,}269$ calories. In this case there will consequently be $10{,}493 - 3{,}269 = 7{,}224$ calories which, in every per cent. of oxidised iron per ton of pig iron, can be utilised for the bath.

3. *With Steam.*—For the combustion of 10 kilos. of iron 2·857

* 1,000 kilos. are taken as equal to 1 ton.

† Jernkontoret's Annaler, Stockholm, 1871, page 102.

kilos. of oxygen is required, and consequently $2 \cdot 857 \times 9 : 8 = 3 \cdot 214$ kilos. of steam, which contains 0·357 kilos. of hydrogen. The quantity of heat generated by the combustion of 10 kilos. of iron amounts, as in the foregoing cases, to 10,493 calories, but if the injected steam has a temperature of 100 deg. C., the amount of heat thus introduced must be added, which makes $3 \cdot 214 \times 0 \cdot 475 \times 100 = 153$ calories, so that the whole quantity of heat generated per ton of pig iron by the oxidation of 1 per cent. of the iron in this case amounts to $10{,}493 + 153 = 10{,}646$ calories.

On the other hand, there will be required for the decomposition of the steam $0 \cdot 357 \times 29{,}638^{*} = 10{,}581$ calories, and if the hydrogen set free in the process should escape at a temperature of 1,400 degs., and its specific heat were 3·40, it would carry away from the bath $0 \cdot 357 \times 3 \cdot 40 \times 1{,}400 = 1{,}699$ calories. The total consumption of heat would, therefore, be $10{,}581 + 1{,}699 = 12{,}280$ calories. For every per cent. of iron oxidised by means of steam there would consequently be a decrease of heat per ton of pig iron equal to $12{,}280 - 10{,}646 = 1{,}634$ calories.

This diminution of heat, caused by the oxidation of iron with water, cannot in reality, however, be quite so considerable, for in the first place the hydrogen in passing off, cannot carry so high a temperature as 1,400 degs., because in this case the initial temperature of the bath is not increased, but is, on the contrary, reduced; and in the second place it cannot, for reasons which will hereafter be more fully explained, be correct to set down the specific heat of the hydrogen as high as 3·40, inasmuch as this figure represents its specific heat under constant pressure, while its specific heat, at a constant volume, is only 0·2356. Some intermediate value between these two figures would therefore be the right one in this case, but it is difficult to define it, depending, as it does, on the pressure of the gas in the flue of the furnace, or in the aperture for the escape of the gases from the converter.

Now, if the quantity of heat carried away by the hydrogen is computed on the assumptions that its specific heat is only 0·236, and that the hydrogen, when escaping, has only a temperature of 800 degs., the loss of heat here in question would be limited to $0 \cdot 357 \times 0 \cdot 236 \times 800 = 67$ calories, and the total consumption of heat

* The calorimetrical heating effect of hydrogen is commonly set down at 34,462 calories, but for such calculations as the following the condensation or evaporation heat of the water which is formed, say, $9 \times 536 = 4{,}824$ calories should be deducted from this.

would amount to $10{,}581 + 67 = 10{,}648$ calories, which at any rate does not fall short of the generation of heat (10,646 calories), from which it is evident that in the combustion of iron with steam a reduction of heat must always take place.

COMBUSTION OF MANGANESE.

The calorific effect of manganese, as far as the author is aware, is as yet unknown, but inasmuch as its equivalent weight not only scarcely differs from that of iron, but also the specific heat of the oxide of manganese very clearly coincides with that of the oxide of iron, it is assumed by Mr. Jordan that the calorimetrical heating effects of these substances must correspond pretty closely. The specific heat of manganese is, however, higher than that of iron, and the protoxide of manganese, in particular, is a good deal more difficult to reduce than the protoxide of iron, and it seems, therefore, on these grounds, to be not altogether unreasonable to assume that the calorific effect of manganese is considerably higher than that of iron. The strongest support for this theory is, however, afforded by the great development of heat which generally distinguishes the treatment, according to the Bessemer method, of such kinds of pig iron as contain any appreciable admixture of manganese; but until the calorific effect of manganese shall have been ascertained by direct experiments, there can, naturally, be no question of calculations as to the quantity of heat generated by the oxidation of that substance.

COMBUSTION OF CARBON.

1. *With Oxygen.*—To convert into carbonic oxide 10 kilos. of carbon or 1 per cent. of the quantity of pig iron taken as a normal, will require $\frac{10 \times 8}{6} = 13{\cdot}33$ kilos. of oxygen gas. Whether this combustion is effected directly or by indirect action, that is to say, by the oxidation of iron and the reduction again of this iron through the carbon, its result ought, under ordinary circumstances, when combustion, as in the Bessemer process, takes place in a bath of molten iron, to consist in carbonic oxide, for the carbonic acid which may possibly have been formed must be assumed to have been

instantly reduced by the molten iron* under the influence of a temperature very highly elevated. Reasons are, therefore, in all probability not wanting for supposing that the quantity of heat generated by the combustion of carbon into carbonic oxide. By the combustion in question there ought, consequently, under ordinary circumstances to be formed 23·33 kilos. of carbonic oxide, resulting in the generation of 24,730 calories.

If the carbonic oxide, when escaping, possesses a temperature of 1,400 deg., it will, however, deprive the bath of

$$\{23{\cdot}33 \times (0{\cdot}2479 - 0{\cdot}241)\}\ 1400 = 4718$$

calories, and there will consequently remain 24,730—4,718=20,012 calories per ton of pig iron, for every hundredth part of carbon burnt with pure oxygen, available for the further heating of the metal.

2. *With Atmospheric Air.*—In order to convert 10 kilos. of carbon into carbonic oxide, there is required 13·33 kilos. of oxygen, which, in the atmospheric air, is intermixed with $13{\cdot}33 \times 77 : 23 = 44{\cdot}66$ kilos. of nitrogen.

The quantity of heat generated by this combustion amounts, as in the case last mentioned, to 24,730 calories, but of these 4,718 calories are carried away with the carbonic oxide which has been formed, and $44{\cdot}66 \times 0{\cdot}244 \times 1{,}400 = 15{,}260$ calories with the nitrogen, so that there only remains for the heating of the bath per ton of pig iron $24{,}730 - (4{,}718 + 15{,}260)\dagger = 4{,}752$ calories for every per cent. of carbon which has been oxidised by means of atmospheric air.

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* It has been now long known that the combustion of iron can be effected by means of carbonic acid, and that this faculty of iron to reduce carbonic acid, increases with the degree of heat; but Mr. Bell, in his paper on "Chemical Phenomena of the Iron Smelting," published in the "Journal of the Iron and Steel Institute, 1871," has also shown that this reaction increases more rapidly with the elevation of temperature than the opposite one, or the reduction of oxidised iron by carbonic oxide, and that a jet of carbonic acid, passed over iron sponge at about 400 deg., was so completely transformed into carbonic oxide, that after contact with this iron, the gas consisted of 96 vol. per cent. of carbonic oxide and 4 vol. per cent. of carbonic acid.

† Neither in this nor in any of the other calculations has any account been taken of the modification caused by the carbonic oxide, as well as the nitrogen, having a greater pressure in the Bessemer furnace than in the surrounding atmosphere. Instead of the specific heat of the carbonic oxide and the nitrogen at constant pressure being respectively 0·2479 and 0·2440, they are, at constant volume, 0·2399 and 0·237, and the quantities of heat carried away by the gases would, with these values attached to their specific heat, be $\{(23{\cdot}33 \times 0{\cdot}2399 - 0{\cdot}241)\}\ 1{,}400 + (44{\cdot}667 \times 0{\cdot}237 \times 1{,}400) = 4{,}462 + 14{,}828 = 19{,}290$ calories. Adopting this opposite extreme, there would remain for heating the bath per ton of pig iron $24{,}730 - 19{,}290 = 5{,}440$ calories for every per cent. of carbon oxidised with atmospheric air.

3. *With Steam.*—To convert 10 kilos. of carbon into carbonic oxide 13·33 kilos. of oxygen are required, to produce which it will take 15 kilos. of steam, containing, besides the oxygen, 1·667 kilos. of hydrogen. To decompose this quantity of steam $1·667 \times 29,638 = 49,407$ calories are absorbed, and if the hydrogen entered at 100 degs., and passed away at 1,400 degs., it would have deprived the bath of $1·667 \times 3·4 \times 1,300 = 7,367$ calories, so that the total consumption of heat amounts to $49,407 + 7,367 = 56,774$ calories.

The generation of heat, on the other hand, amounts to the same as when the carbon is oxidised with pure oxygen, or $24,730 - 4,718 = 20,012$ calories, to which, in this case, must be added, however, the quantity of heat introduced with the oxygen, consisting of $13·33 \times 0·218 \times 100 = 290$ calories, so that the total generation of heat amounts to $20,012 + 290 = 20,302$ calories. The quantity of heat taken away from the bath for every per cent. of carbon per ton of pig iron oxidised by steam would, therefore, amount to 56,774—20,302=36,472 calories.

Were it practicable to estimate correctly the loss in specific heat sustained by the gases in consequence of their condensation, a much reduced value would, no doubt, be arrived at for the decrease of heat in question when narrow funnel-apertures are employed; but a comparison with the calculations made in this respect, as will be shown hereafter, will easily indicate that, even if the specific heat of hydrogen were only estimated at 0·2356, and that of carbonic oxide at 0·2399 the combustion of carbon with steam would nevertheless bring about so great a reduction in temperature that the iron could not be kept in a liquid state without an extraneous accession of heat.

COMBUSTION OF SILICON.

1. *With Oxygen Gas.*—For the combustion of 10 kilos. of silicon or 1 per cent. of the assumed weight of pig iron, $24 : 21 = 11·429$ kilos. of oxygen are required.

By this combustion 78,300* calories are produced, but a portion of this heat is consumed in heating the silica which has been formed to a temperature equal to that of the bath. To be able to state how much heat is absorbed for this purpose, it would be necessary

* The calorimetric effect of silicon is, according to Troost and Hautefeuille (Dingler's Journal, vol. 197, page 55), 7,830 calories.

to know the difference in specific heat, between silica and silicon; but until this difference becomes known it must suffice to assume the amount of heat in question to be equal to that which is required to raise the temperature of the injected oxygen gas to 1,400 degs., or $11{\cdot}429 \times 0{\cdot}218 \times 1{,}400 = 3{,}488$ calories. There remains consequently in this case, per ton of pig iron, for heating the bath, the enormous quantity of $78{,}300 - 3{,}488 = 74{,}812$ calories for every per cent. of silicon oxidised with pure oxygen gas.

2. *With Atmospheric Air.*—For the combustion of 10 kilos. of silicon, 11,429 kilos. of oxygen are required, which in atmospheric air is intermixed with $11{\cdot}429 \times 77 : 23 = 38{\cdot}261$ lb. of nitrogen, which in escaping deprives the bath of $38{\cdot}261 \times 0{\cdot}244 \times 1{,}400 =$ 13,070 calories.

During this combustion there are, as in the foregoing case, 74,812 calories produced, and for every per cent. of silicon oxidised with atmospheric air the amount of heat in the bath is consequently increased, per ton of pig iron employed, by $74{,}812 - 13{,}070 = 61{,}742$ calories.

3. *With Steam.*—To the amount of heat produced by the oxidation of 10 kilos. of silicon, say 74·810 calories, must in this case be added the heat introduced with the oxygen at a temperature of 100 degs., which amounts to $11{\cdot}429 \times 0{\cdot}218 \times 100 = 24{\cdot}9$ calories. The total generation of heat, therefore, amounts in this case to $74{,}810 \times 249 = 75{,}061$ calories. For this the necessary quantity of oxygen, is, however, first to be obtained by the decomposition of 12·858 kilos. of steam, which contain 1·429 kilos. of hydrogen, and to effect this decomposition 1·429 kilos. $\times 29{,}638 =$ 42,353 calories are consumed, besides which the hydrogen escaping from the bath carries away $1{\cdot}429 \times 3{\cdot}40 \times 1{,}300 = 6{,}316$ calories. There are consequently consumed in all $42{,}353 + 6{,}316 = 48{,}669$ calories, so that for heating the bath there remains in this case per ton of pig iron employed $75{,}061 - 48{,}669 = 26{,}392$ calories for every per cent. of silicon oxidised with steam.

Even assuming the higher value of the specific heat of hydrogen, there arises consequently, in this case, an increase of temperature, but it is very remarkable, however, that this only takes place during the combustion of silicon, for the oxidation of iron, and especially of carbon, by means of steam produces, on the contrary, a cooling effect. By this, moreover, is also explained the circum-

stance that the advantages which at times seem to accrue from the use of steam are chiefly experienced at the commencement of the converting process by puddling.

To obtain a more comprehensive view, we will now group together, in one table, the conditions of heat which arise during the combustion, with atmospheric air, of a unit in weight of the principal substances present in pig iron, viz., iron, carbon, and silicon.

The oxidation of 10 kilos. of	Iron.	Calories.	Carbon.	Calories.	Silicon.	
	kilos.		kilos.		kilos.	
Requirements of atmospheric air	12·42	...	47·99	...	49·69	...
Which contains: oxygen	2·85	...	13·33	...	11·43	...
nitrogen	9·57	...	44·66	...	38·26	...
In the combustion are generated	...	12,013	...	24,730	...	78,300
From these deduct the heat which is ...						
(*a*) carried away with the carbonic oxide	...	...	4,718	...	...	...
(*b*) absorbed by the slag	1,520	...	...	...	3,480	...
(*c*) carried away with the nitrogen..	3,269	...	15,260	...	13,070	...
Or in all	...	4,789	...	19,978	...	16,558
For heating the bath there consequently remain, per cwt. of pig iron employed, for every per cent. of the respective substances which has been oxydised ...	...	7,224	...	4,572	...	61,742

With reference to this table it should, however, once more be observed, in the first place, that the specific heat of the gases has been calculated as if the gases had always had the opportunity of free expansion, or, in other words, as if their pressure had been equal to that of the exterior air, and in the second place, that no account has been taken of the heat conducted away and radiated by the walls of the furnace; also that the products of combustion have been assumed to pass off from the bath at the same temperature as the latter was considered to possess at the commencement of the process, viz., 1,400 degs. C.

Messrs. Jordan and Kupelweiser assume, as before intimated, the caloric effect of manganese to be the same as that of iron, and do not, therefore, ascribe to the manganese contained in Bessemer pig iron any beneficial influence on the heating process. In as far as the temperature depends on the composition of the pig iron, they consider, in accordance with the calculations here imparted, that it is virtually determined by the proportion of silicon present in the pig-iron bath, which, to produce a sufficient degree of heat, should amount, it is estimated, at the very least, to 1·25 per cent.

The figures presented above appear in fact to make it clear that the charge must become more heated the more silicon is contained in the pig iron, provided only that the blast is strong enough to allow the process to be completed with sufficient rapidity, notwithstanding the presence of a larger proportion of silicon,* and also that the bath is deep enough for the complete utilisation of the oxygen in the blast, even if by reason of the increased proportion of its silicon the pig iron should have become less disposed to absorb oxygen, of which tendency we shall have more to say further on. But even admitting this powerful action of silicon in generating heat, it in nowise follows as a necessary consequence that the presence of manganese may not exercise a much greater influence on the generation of heat in the Bessemer process than Messrs. Jordan and Kupelweiser have assumed. That such is indeed the case seems to be demonstrated by the experience acquired at one or two Swedish Bessemer works, and as a proof of this it may suffice to state that at one of the said works, where the pig iron usually contains nearly 3 per cent. of manganese, but only the inconsiderable portion of 0·7 per cent. of silicon, the charge generally seems to have a higher temperature than at most other Bessemer establishments. It is by no means to be inferred from this, however, that the charges at the works in question might not be still hotter if the force of the blast-apparatus would allow of a greater proportion of silicon in the pig iron; but under all circumstances it seems to follow as an undoubted consequence that in this respect the presence in the Bessemer pig iron of a proportion of manganese up to as much as 3 per cent., must be very desirable. Whether this, on the other hand, is particularly advantageous as regards the final result is a matter which cannot probably be so unconditionally affirmed; for a Bessemer pig iron holding much manganese will sometimes produce a steel very much impregnated with that substance, and there are, at any rate, not wanting reasons for supposing that steel, as well as iron, holding a considerable portion of manganese, will be more sensible to concussion than those metals more free from manganese, and that the presence of manganese increases the tendency to crack, and causes the iron to act with a greater corrosion on the moulds. Be this as it may, however, it is a fact that most of the Swedish blast furnace charges are not in any appreciable degree impregnated

* See *Illustrated Technical Journal*, Stockholm, 1871, page 107.

with manganese; and at such places where the Bessemer process is to be adapted to charges so impregnated, it is all the more necessary, in order to obtain a hot charge, that the blast apparatus should have sufficient force* to enable the operator to employ a pig iron tolerably rich in silicon.

As long as the calorimetric heating effect of manganese remains unknown, it is plain that it cannot be stated, in exact figures, how much heat its combustion furnishes to the Bessemer process; but on the other hand, the amount of heat available for the bath when a pig iron free of manganese is treated according to the said process, can always be easily computed, with the assistance of the calculations shown in the foregoing, provided only that it can be demonstrated what quantity of each particular substance is oxidised in the process.

Messrs. Jordan and Kupelweiser estimated these quantities in a normal Bessemer process at 2 per cent. of silicon, 4·25 per cent. of carbon, and 8·75 per cent of iron; but, as corresponding more closely with the condition of our Swedish iron manufacture, I will assume them to be

1·00	per cent.	silicon
4·25	„	carbon
6·00	„	iron

There would in this case be available, per cent. of pig iron employed, to increase the temperature of the bath during this process:

$1{\cdot}00 \times 6174{\cdot}2 = 6174{\cdot}2$		calories.
$4{\cdot}25 \times 475{\cdot}2 = 2019{\cdot}6$		„
$6{\cdot}00 \times 722{\cdot}4 = 4334{\cdot}4$		„
Total	12,528·2	„

The specific heat of molten iron is as yet not known, but as in the case of molten pig iron, it is about 50 per cent. higher than that of pig iron from 0 degs. to 200 degs., and as the specific heat of iron at the usual degree of temperature is 0·11, the specific heat of molten iron may be set down at about 0·16. The temperature of the bath would in consequence be increased, during the process, to the extent of 12,528 : 16=783 degs., and as its original temperature was 1,400 degs., the final temperature would, in that case, be

* See *Illustrated Technical Journal*, Stockholm, 1871, page 115.

about 2,200 degs. As no method has hitherto been invented by which such high degrees of temperature as those just mentioned can be measured, it is obviously impossible to know for certain how nearly this estimated degree of heat coincides with the real fact; but that the figure derived from the said calculations cannot be far from the truth seems to be established by Kupelweiser's observations on the fusibility of platina in molten Bessemer metal. During his experiments at Heft, he found that a tolerably thick piece of platina wire, inserted in the jet of soft iron running out from the Bessemer furnace, was fused in a few seconds, but when a little specular iron had been added to the ladle, and the steel had been run into the moulds, a platina wire inserted in the still perfectly liquid metal was not fused at all. As the degree of heat requisite to fuse platina is, according to the investigations of Sainte Claire Deville, below 1,900 degs., it would appear that the temperature of 2,200 degs. assigned to the Bessemer iron, on completion of process, has much probability.

In the foregoing has been shown what influence is exercised by the composition of the pig iron on the amount of heat generated in the Bessemer process, but the temperature attained is not, however, exclusively dependent on this and on the specific heat of the bath, but also on the time required for the combustion, inasmuch as the loss of heat by external cooling must be greater in proportion as the process is protracted. It is therefore not enough that certain percentages of the substances entering into the composition of pig iron undergo combustion during the process, for unless a considerable portion of the heat generated thereby is to be wasted, the combustion must, besides, be effected with great rapidity; but for this purpose an abundant supply of blast is necessary, a supply which cannot be procured except by a powerful blast apparatus.*

The degree of heat imparted to the walls of the furnace before the introduction of the pig iron will also considerably influence the cooling which takes place through radiation from the said walls, besides which it is evident that the amount of heat lost per weight unit of pig iron through the walls must be less in proportion as the quantity of pig iron under treatment is increased, for if the furnaces

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* Respecting the basis of calculation of the force required for the blast of the Bessemer furnace, see article in the *Illustrated Technical Journal*, of Stockholm, cited in a previous note.

are properly constructed the surfaces of their walls will not be augmented in a ratio proportionate to the space within, from which it follows that the loss of heat will be comparatively less in working with greater charges.

In the calculations of heat hereinbefore specified, no account has been taken of the cooling through the walls just mentioned, and as this cooling cannot be entirely prevented, even with the best heated furnaces and the heaviest charges and the greatest acceleration of the process, it is evident that the conclusions as to temperature mentioned above must be a little too high, unless the cooling in question may be compensated by the circumstance that, on the other hand, no account has been taken of the rise in temperature which must be caused by the gases leaving the furnace under a pressure depending on the size of the nozzle, but more or less exceeding that of the atmospheric air.

When gases expand it is known that they absorb heat, which is again liberated on their being condensed in a corresponding degree. It is evident, therefore, that the higher the pressure sustained by gases on their escape from a furnace, the less heat do they carry away with them, and the higher, consequently, will the degree of temperature in the furnace be, other conditions being assumed to be equal. From this it follows that the narrower the aperture is for the escape of products of combustion from a Bessemer furnace, the hotter the charge must be, provided always that the blowing apparatus has force enough to be capable of pressing in the same quantity of air, notwithstanding the increased resistance, so that the process is not retarded by reason of the contracted aperture of the nozzle.

As already stated, no account has been taken in the foregoing calculations as to heat, of the rise in temperature occasioned by the circumstance just adverted to, but owing to the difficulty of determining which of the figures comprised between the two extreme limits denoting the quantities of specific heat (for constant pressure and constant volume) may be the correct ones, they have, in accordance with M. Jordan, simply been estimated at the same degrees as if the gases, in escaping from the Bessemer furnace, had only the pressure of the surrounding atmosphere. That component part of the pig iron, the calorific action of which, during combustion with atmospheric air, has the least justice done to it by this estimate is

the carbon, inasmuch as the combustion of this substance produces the greatest quantity of gas; but in order to indicate the limits within which the error thus committed must lie, it has been explained in a foot-note how the result would turn out if it could be allowed to compute the specific quantities of heat in the gases as low as in their state of constant volume.

The calculations of heat presented in the foregoing are based on the assumption that during the rising of the atmospheric air through the Bessemer bath, the whole of its oxygen is completely utilised, so that only the nitrogen contained in the blast, but no part of its oxygen, escapes from the bath in a free form. If, on the other hand, the oxygen should not be completely absorbed by the metal, a loss of heat will be the natural consequence; in the first place because the generation of heat in a certain moment of time is diminished in the same proportion as the utilisation of oxygen is lessened, or the refining process retarded; and in the second place, because the free oxygen, just like the nitrogen, absorbs heat, which escapes, without profit, with the oxygen from the furnace. The waste of produce, moreover, will also be somewhat increased by this, because the gases which fill the furnace are, in this case, oxidised, and, therefore, in their turn, oxidise a portion of the iron bubbling at the surface, partly converting it into oxide of iron, which is not retained in the slag, but escapes as a reddish-brown smoke with the gases.

If the air is forced too quickly through the bath the latter will not have time to absorb the whole of the oxygen, and the more or less complete utilisation of that substance by the same description of pig iron, depends, in consequence, on the time occupied by a particle of air in ascending through the bath. Again, the time of contact between the metal and the blast is increased with the depth of the bath, but decreases with the pressure of the blast, and it is clear, therefore, that already, on this account, the depth of the bath and the pressure of the blast must be made in some measure to correspond. Furthermore, it is hereby made equally clear that in a cupola converter with vertical tuyeres placed at the bottom, so shallow a bath cannot be profitably employed as will be practicable in a Bessemer converter with horizontal tuyeres, for in the first-mentioned description of converter, the blast goes the nearest way straight up through the bath, while, in fixed converters, on the

contrary, it must describe a curved-line chiefly depending as to extent on the pressure of the blast and the depth of the bath. Even in a cupola converter, however, the depth of bath need probably not require to be increased in full proportion to the blast pressure, for the stronger this pressure is, or the harder the blow of the blast, the more intimate should the contact become between the air and the particles of iron, and the more easily would, therefore, the metal be enabled to absorb or utilise the oxygen.

The absorption of oxygen does not appear, however, to depend exclusively on the circumstances hitherto dwelt upon, but just as different descriptions of pig iron at their tapping from the blast furnace already show different dispositions for being oxidised, some of them sparkling or burning a great deal more than others,* so it has, in like manner, appeared at the Swedish Bessemer works, as if Bessemer pig irons of different compositions were more or less ready to absorb oxygen; a grey pig iron seeming to require a longer period of contact between the particles of air and iron and a stronger blast pressure, for a complete absorption of the oxygen of the blast than a less grey or white iron. It is, therefore, necessary, in order completely to utilise the oxygen of the blast to increase the depth of the bath in proportion to the quality of the pig iron In the contrary case, or if while employing a more than usually grey pig iron, the depth of the bath should be made as shallow as could possibly be compatible with the absorption of the oxygen by a whiter, or No. 3 of pig iron, it would, in most cases, happen during the first so-called refining or slag-forming period, that the before-mentioned reddish-brown smoke which is produced by an incomplete utilisation of the oxygen, would make its appearance, accompanied, moreover, and from causes explained above, by a decrease of heat in the process.

Although, under usual circumstances, the silicon is mostly oxidised before the carbon, or during the slag-formation period, while the combustion of the carbon principally takes place during the boil and the after-refining, it is nevertheless probable that the chief cause of a lessened disposition in pig iron to absorb oxygen

* The difference in degree of temperature of the pig-iron exercises no doubt in this respect a very material influence, causing the warmer of two otherwise similar descriptions of pig-iron to burn fiercer than the cooler of the two; but it is a known fact, that even if the temperature is the same, two different classes of pig-iron may exhibit a very dissimilar disposition to burn or throw sparks while running out from the blast furnace.

will be found in the larger proportion of silicon which it contains. It has already been shown in the foregoing, that the richer in silicon the Bessemer pig iron is, the hotter will the charge become, provided that the greater admixture of silicon does not retard the process too much, nor prevent a complete utilisation of the oxygen of the blast. But in order that these conditions may be fulfilled, it is again evident from the reasons above given, that the more grey and the more rich in silicon is the pig iron to be operated upon, the more abundant must the supply of blast be, and in consequence, the greater is the force required; the more so as a very dark and graphitic pig iron usually is comparatively thick-flowing, and, consequently, offers greater resistance to the blast.

One foot is considered about the ordinary depth of bath for the Bessemer vessel. Less than that would hardly suffice to insure proper success when making use of a moderately hard pig iron free from manganese, and a pretty considerable blast pressure.

Having thus, in general outline, touched on the usual circumstances which produce more or less heat in the charge of a Bessemer furnace, we will now, in conclusion, endeavour to ascertain also what influence, in this respect, may be expected from sundry projects, either already essayed in some place or another, or altogether untried, to obtain sufficient heat in the Bessemer process, even with a No. 3, or white pig iron.

As, generally speaking, no separate fuel is employed in the Bessemer process, it readily suggests itself to try the use of such fuel for raising the temperature in this process as in others. With this view experiments were commenced at Neuberg as early as the year 1867, to inject charcoal dust with the blast,—a procedure which is said to have been afterwards generally continued at that place, and likewise to have been tried, at least at intervals, at some other Bessemer works. That the degree of heat will be somewhat increased hereby is natural; but it is equally obvious that if the process is to be finished off with the same rapidity when charcoal dust is being injected as when it is not, the supply of blast must be more abundant than otherwise, inasmuch as part of the air is consumed for combustion of the injected charcoal. The main question is, however, whether the charcoal employed in this manner is utilised to greater or less advantage than if it were used in the blast furnace to produce a more grey, or No. 1 pig iron.

As it has been already shown, the combustion of 10 kilos. of the carbon of the Bessemer bath, with atmospheric air, produces an increase in heat of 4,752 calories; but the injected charcoal dust does not possess the same temperature as the carbon contained in the pig iron. It must first be heated up to that point in the bath, for which purpose $2 \cdot 4 \times 1{,}400 = 3{,}360$ calories are consumed, and the accession of heat obtained by combustion of 10 kilos. of injected charcoal dust is consequently reduced to $4{,}752 - 3{,}360 = 1{,}392$ calories, which would scarcely suffice to raise the temperature of 1 ton of molten iron 9 degs. Were the object, therefore, by the injection of charcoal dust, to make up for the heat generated by a portion, say 0·5 per cent. of silicon contained in the pig iron, it would be necessary, inasmuch as the combustion of 0·5 per cent. of silicon increases the heat of the Bessemer bath by $61{,}742 \times 0 \cdot 5 = 30{,}871$ calories, to inject $30{,}871 : 1{,}392 = 222$ lb. of pure carbon, or nearly 5 barrels of charcoal for every ton of pig iron.

As, moreover, Professor Kupelweiser has made the observation that a portion of the charcoal dust has not, in point of fact, the time requisite to be consumed in the metallic bath, but that its combustion is first effected outside of the neck of the retort, it seems to be clear that the action of so inconsiderable a charcoal injection as it is customary to make at Neuberg, or 3 to 5 per cent. of the weight of the pig iron, cannot produce any very appreciable effect; in full confirmation of which Herr Kupelweiser has also stated that it can scarcely be discerned by impartial investigators. It further follows from this that it can hardly be in accordance with good economy, as long as cold blast is used, to substitute an injection of charcoal dust into the Bessemer furnace for the consumption of charcoal which would be requisite to produce in the blast furnace a pig iron sufficiently grey to obtain by it a high degree of heat in the Bessemer process, especially as such can be produced without any additional consumption of charcoal, if only the stove is powerful enough to supply the blast furnace with a highly heated blast.

A plan, advocated by Messrs. Styffe and Tunner, to raise the temperature in the Bessemer process, is to employ heated blast, and a prize of 1,000 florins has been offered in Austria for a successful realisation of this idea.

Having regard to the great amount of blast-power required for the Bessemer process, and to the considerable quantity of gases which in a highly-heated state escapes from the furnace, it is not difficult to conceive that the heating of the blast ought to insure material advantages, but for this purpose it is necessary that the blowing apparatus shall be sufficiently powerful to be able, notwithstanding the attenuation of the air caused by its higher temperature, to force in so large a volume of it that the process may be completed with the requisite rapidity.

If the additions of heat, which are supplied to the Bessemer bath by combustion with atmospheric air at different degrees of temperature of 10 kilos. of iron, carbon, and silicon, are calculated in the same manner as has previously been done with unheated blast, and if the specific heat of oxygen is assumed to be 0·2182, the following quantities of heat will result:

	Deg. Temp.	Of 10 kilos. of Iron. Calories.	Of 10 kilos. of Carbon. Calories.	Of 10 kilos. of Silicon. Calories.
With blast of ...	0	7,224	4,752	61,742
„ ...	100	7,520	6,133	62,925
„ ...	200	7,816	7,514	64,100
„ ...	300	8,112	8,895	65,291
„ ...	400	8,408	10,276	66,474
„ ...	500	8,704	11,657	67,657
„ ...	600	9,000	13,038	68,840

The greater the quantity of oxygen required for the combustion of any given substance, the greater will naturally be the accession of heat obtained from the heating of the air by that substance. Consequently the accession of heat obtained, by heating the blast, is comparatively greater from the carbon than from either of the other substances.

Let us now see what accessions of heat would be produced with blasts of different temperatures per ton of Bessemer pig iron of such a description that in conversion there would be oxidised at a blast temperature—

	Of 0 dg calories.	Of 100 dg calories.	Of 200 dg calories.	Of 300 dg calories.	Of 400 dg calories.	Of 500 dg calories.	Of 600 dg calories.
1·00 per cent. of silicon ...	61,742	62,925	64,108	65,291	66,474	67,657	68,840
4·25 „ carbon ...	20,196	26,065	31,934	37,804	43,673	49,542	55,411
6·00 „ iron ...	43,344	45,120	46,896	48,672	50,448	52,224	54,000
	125,282	134,110	142,938	151,767	160,595	169,423	178,251

These accessions of heat would—if the specific heat of the molten iron is assumed to be 0·16, and no account is taken of the slag which had been formed—for the several degrees of temperature of the blast correspond to the following increments in the temperature of the bath:

Degrees.						
783	838	894	948	1,004	1,059	1,114

It is clear, therefore, that if the bath of Bessemer pig iron, in order to attain a sufficiently high degree of temperature, only requires the accession of a certain amount of heat, it is possible to employ in the Bessemer process, without detriment, a pig iron less grey in proportion as the temperature of the Bessemer blast is raised. In this manner it is easy to calculate that, with a blast heated to 500 degs., there should not be required a greater proportion than 0·35 per cent. of silicon in the pig iron to obtain as great a heat during the process as can be produced with a pig iron containing 1 per cent. of silicon when the blast is not heated. But, as has been stated above, it is necessary for this purpose that the blast apparatus should be so powerful that the conversion with heated blast can proceed as rapidly as with cold; and if to this is added, first, the circumstance that the loss of heat in a Bessemer heating apparatus must be very considerable in places where the intervals between the blowings are so long, as is usually the case with us in Sweden, and then and principally the increased difficulty which undoubtedly arises from the heating of the blast, to keep the tuyeres in proper order, it may perhaps still be a question whether it will not be cheaper, when the injection of charcoal dust is not simultaneously resorted to, to procure, with the assistance of powerful heating apparatus for the blast furnace, and without extra consumption of charcoal,* a sufficiently grey, or No. 1 pig iron, to be able to dispense with the Bessemer blast heating apparatus altogether.

If, on the other hand, the Bessemer hot blast can, in some way, and without the too rapid destruction of the tuyeres, be combined with the injection of charcoal dust, its action ought, as was first pointed out by Kupelweiser, to be very powerful; and it would even appear as if in that case a pig iron, almost as poor in silicon as that used for refining in the charcoal hearth process, might be

* See the "Annals of the Iron Office, Stockholm, 1871," p. 268.

employed with advantage in the Bessemer process. For 10 kilos. of charcoal burnt in air heated to 500 degs. would increase the heat of the Bessemer bath by 11,657 calories, while 3,360 calories would be required to heat the charcoal from 0 deg. to the initial temperature of the bath; and the accession of heat produced by 10 kilos. of charcoal would therefore, in this case, amount to $11{,}657 - 3{,}360 = 8{,}297$ calories. The quantity of heat infused into the Bessemer bath by the combustion of 0·5 per cent. of silicon with cold air, might, therefore, when the blast is heated to 500 degs., be indemnified by the injection $0{\cdot}5 \times 61{,}742 : 8{,}297 = 37$ kilos. carbon, or about 0·7 of a barrel of charcoal per ton of pig iron. To arrive at a correct estimate of the effect produced by the Bessemer hot blast in combination with the injection of charcoal dust, it should be observed, in conclusion, that in the calculation last made no account has been taken of the influence which the heating of the blast to 500 degs. in itself exercises on the temperature of the bath; but about this something had been said previously.

Another method of raising the temperature in the Bessemer process would be to inject oxygen gas; but in regard to this the question arises, whether such gas can be procured at so low a cost that its use would bring any advantage; and in order to estimate this, we will, in the first instance, examine how great the accession of heat to the bath would be if the conversion were effected with pure oxygen :—

		Calories.
10 kilos. silicon	in combustion with unmixed oxygen increases the heat of the bath with	$1{\cdot}00 \times 74{,}812 = 74{,}812$
42·5 „ carbon		$4{\cdot}25 \times 20{,}012 = 85{,}051$
60·0 „ iron		$6{\cdot}00 \times 10{,}493 = 62{,}958$
		222,821

The amount of heat generated by the oxidation of the above assumed quantities of silicon, carbon, and iron would therefore be sufficient to raise the temperature of the bath nearly 1,400 degs.; and even if all the heat proceeding from the silicon were deducted, the bath ought consequently, when converted with oxygen, to be 100 degs. hotter than has been considered necessary for an average temperature of the process. The use of unmixed oxygen, however, could hardly come into question, but if employed, it would probably

be in an admixture with atmospheric air; and if, in order to ascertain the value of oxygen in this respect, it is desirable to investigate, for instance, how much extra oxygen would have to be mixed with the air to produce the same increase of temperature in the refining of the pig iron above treated of as would result, without an extra admixture of oxygen, by heating the atmospheric air to 500 degs., it will be found that for this purpose the air must be mixed with barely 19 per cent. of its weight, or 17·3 per cent. of its volume of oxygen. The nitrogen present in unmixed atmospheric air takes away from the bath, for every ton of pig iron, 222,821 − 125,282 = 97,539 calories, which loss of heat, if the temperature of the bath is to be the same as when a blast heated 500 degs. is employed, must be brought down to 222,821 − 169,423 = 53,398 calories. But in order to make this possible the quantity of nitrogen per ton of pig iron must not exceed 53,398 : (0·244 × 1400) = 156·32 kilos., which is contained, together with 46·68 kilos. of oxygen, in 202·9 kilos., or 2,536 cubic feet of atmospheric air, while for the said purpose are required 370·6 kilos., or 4,630 cubic feet of unmixed air at 0 deg. temperature and a medium barometric pressure, to which the quantities of air and oxygen are here always reduced. To oxidise the stated proportions, per ton of pig iron, of the several constituents of the pig iron, requires in all, 85·24 kilos. of oxygen, of which consequently in the case before us, 85·24 − 46·68 = 38·56 kilos., or 440 cubic feet per ton of pig iron, must be intermixed with the atmospheric air.

That an entire or partial exchange of the Bessemer blast for steam would not be attended by a higher, but, on the contrary, by a considerably lower temperature than when air alone is employed, can be easily gathered from the calculations presented at the beginning of this memoir, inasmuch as they show that in Bessemer refining with steam it is only the silicon that, in being oxidised, affords any accession of heat, while the oxidation, as well of the iron as especially of the carbon, on the other hand, are attended with a positive lowering of the temperature. As the silicon is chiefly oxidised during the commencement of the process, it is only at that stage, or during the refining period, that there should ever be any question of injecting steam, and the object of so doing would in that case be to eliminate sulphur in some degree, but even at this stage the introduction of steam will produce a less

elevation of temperature than would have been attained by the injection of a corresponding quantity of air.

It has also been proposed to inject, through concentric double tuyeres, air and hydrogen, to form water by combustion, and thus produce an increase of temperature; but the water which is formed in this way would, in ascending through the bath, be again decomposed, and thereby absorb just as much heat as was engendered by its formation. The consequence of such an arrangement could, therefore, hardly be any other than a cooling proportionate to the injection of hydrogen, for no heat can very well be generated by the hydrogen in such a manner. In fact, the latter will in this case rather compare with nitrogen, and will, like that gas, while rising through the bath, absorb heat and then carry it away from the furnace; while, on the other hand, the only heat engendered would have been produced by the injection of air alone.

ON THE UTILIZATION OF BLAST FURNACE SLAG.

By J. J. BODMER.

(Slag bricks were exhibited at the meeting of the Iron and Steel Institute in London, March, 1872.

THE quantity of blast furnace slag produced is so enormous, that it would appear a hopeless task to find means for using it all. The average make of slag is about from 1·3 to 1·75 tons per two tons of pig-iron, which for the production of about $4\frac{1}{2}$ million tons of pig per annum, amounts to no less than from $2\frac{3}{4}$ million to $3\frac{3}{4}$ million tons of slag. In the Cleveland district and other parts of the country, the large cubes of slag as they come from the tubs into which it is run are used for the construction of embankments, for foundations, in reclaiming land from the sea, and when broken up, as road metal. For such like purposes the largest quantities can be disposed of; but there is a limit in that direction too, even in the most rapidly growing centres of manufacture, and up to the present time the tipping of the slag, or the carrying away of the same into the sea, appears to be inevitable. A number of patents have been taken out for means and apparatus for the removal of slag from blast furnaces.

It has been tried to run the slag into moulds for ornamental purposes, but the annealing process, which was indispensably connected therewith, proved too costly, and the sundry processes proposed in that direction have been abandoned. In some parts of the Continent the slag has been run into moulds, or simply holes, dug out near the blast furnace, when it was allowed to cool gradually, and then dug out or quarried, and used as building stone. Whilst, however, on the one hand, we do not see how to make use of the whole quantity, or even of any considerable part of the slag produced, and whilst on the other hand, a number of schemes for turning the slag to account in a manufacturing way have failed, there are nevertheless means by which quantities of that material can be used very profitably, and on that point I beg

to offer a few remarks. There are two ways of using the slag for building purposes, and it is in that direction, after all, that any quantities can be disposed of. Firstly, the application of the slag in the shape of sand. The object I have in view, however, is not so much the disposal of any considerable quantity of the slag, but rather its application to purposes for which it is particularly suited, namely, firstly on account of its chemical properties, for the manufacture of certain classes of cement and cementing compounds; and secondly, in its condition of sand in combination with cementing compounds, or with lime or cements, for the manufacture of artificial stone, for mortar, and for all purposes for which sand is required. There are different means by which the subdivision of slag can be effected. One mode, patented by myself in 1866, consists in the application of two plain rolls running with differential speed. The slag in its viscous condition as it issues from the furnace, is made to pass through the said rolls and drops from the same in the shape of scales of any convenient thickness. From the rolls it may be made to fall on a belt or chain, or into a creeper, which again may discharge itself into trucks.

Such slag, scale, or sand has a peculiar sharpness or grittiness, and being as a matter of course, free from any of the admixtures which often deteriorate sand for building purposes, it has a special applicability to the manufacture of concrete-bricks and other articles. From the shape of scale it is most easily converted into impalpable powder. A mixture of from 6 to 8 parts by weight of slag sand with one part of hydraulic lime, produces a brick, when properly made, which, after two or three weeks, will be less absorbant than a good clay brick by 40 to 50 per cent. The shape of such concrete-bricks made under pressure is perfectly accurate, being made in steel moulds, and the colour of them can be varied from that of a bright grey sandstone down to a dark iron colour. With a systematically arranged set of machinery, such slag bricks can be produced at a small cost. With two of Bodmer's patent hydraulic presses, 80,000 bricks per week can be produced by 12 hands, (6 or 7 men and 5 or 6 boys), engine power 8 to 10 horse-power. In winter the fresh bricks are piled up in a shed to prevent freezing before they have set, after which they are piled out into the open yard, 1,000 of such bricks, London size, weigh 3 tons.

Although the similarity between Puzzolano or Trass, as seen by

comparison of the analyses, is a well-known fact, the slag has not been used as a substitute for those cementing materials. The reason, I apprehend, lies in the difficulty, or rather in the costliness of grinding blast furnace slag. If, however, the slag is not allowed to form into hard lumps to begin with, that difficulty falls to the ground, and the rolling process as above described, satisfactorily disposes of that question.

COMPARATIVE ANALYSES.

(Blast Furnace Slag).

	Cleveland District.			Wales.		Trass.	Puz-zolano.	Portld. Cement
Silica	36·20	40·75	34·	49·50	45·	57·	44·50	24·31
Alumina	26·	24·47	24·33	15·20	16·42	12·	15·	7·50
Lime	27·	24·50	34·	19·70	26·78	2·60	8·80	60·05
Gypsum	...	...	...	...	...	...	...	1·82
Magnesia	9·	7·17	5·88	3·	0·40	1·	4·70	1·17
Protoxide of Iron	1·30	2·05	0·07	8·82	5·20	5·	12·	3·34
Potash	...	...	...	...	0·46	7·	1·40	0·80
Soda	...	...	...	...	...	1·	4·	0·74
Sulphur	0·40	0·65	1·72	1·29	...	...	...	...
Water...	...	...	...	...	...	9·40	9·20	...
Protoxide of Manganese ...	...	...	...	...	5·64	...	...	...

From the above figures it is evident that, by the addition of a certain proportion of lime, a good cement can be produced, and at a vastly less cost than any of the Portland cements in the trade Some slag, when subdivided as described, and ground together with lime to an impalpable powder, forms a strong and reliable cement. In 1869 a patent was granted to me for that process; and as far back as 1866 I made samples of cement from Ponty-pool cold-blast furnace slag and Abersychan-lime, in the proportion of seven parts by weight of the former to one part of lime.

The following are the results of some of the tests as compared with Portland Cements:—

Figures taken from experiments made on the strength of Portland Cement, by Mr. John Grant, M.I.C.E., 1866.			SLAG-CEMENT. Experiments made by J. J. Bodmer, 1866.		
Weight of Cement per bushel. lbs.	Age after gauging.	Tensile strain sustained per 1 square inch. lbs.	One part by Weight of Lime, with 7 parts of Slag.	Age after Gauging.	Tensile strain per 1 square inch.
106·7	7 days.	157·6			
107·6	,,	156·56			
111·75	,,	201·63			
114·15	,,	269·78		7 days.	271·22
119·04	,,	248·03			
119·07	,,	305·89			
121·0	,,	409·77			
,,	14 ,,	472·26			
,,	28 ,,	499·51		1 month.	472·18
,,	2 months.	522·44			
,,	3 ,,	558·62			

Now, whilst to a great extent the composition of Portland cement can be regulated, the blast furnace slag, from well-known causes, alters materially; and unless a furnace was worked with the same charge, and the slag was used at the same point of greyness uniformly, a quality of cement equally reliable at all times could not be produced. But, on the other hand, it is certain that an energetic hydraulic compound can be made of all but the worst black slag. The latter sets also, but slower, and without attaining the same degree of hardness as the cement made from gray iron slag. According to the purposes for which the material is intended, the slag cement can be varied from the composition and strength of Portland cement, down to that of a simple hydraulic lime. When used in the manufacture of bricks, the setting time and the ultimate absorption of the bricks are in proportion to the quantity and quality of the slag-cement used. For instance, from a slag-cement of seven parts of slag and one lime worked together,

with an equal weight of slag sand, bricks are produced which after a short time are practically non-absorbant. The quantity of the slag-sand used in the manufacture of the brick can be increased in proportion to the quantity of lime used in the manufacture of the slag-cement, up to one part of such cement to seven parts of slag sand. We have, therefore, the means of manufacturing bricks from the cheapest possible materials, and varying at will in quality and colour. The new and interesting mode of dealing with sewage-precipitates, by Major-General H. Y. D. Scott, C.B., will enable all large towns to convert the sewage into a hydraulic lime or cement, at a cost of something like 9s. or 10s. a ton; and when that process is fairly introduced, two descriptions of material (sewage and slag), hitherto difficult of disposal, will be manufactured into building material of excellent quality, and for which there will be at all times a great demand. The bricks exhibited at the aforesaid meeting were in part made of slag cement and slag in the condition of sand, and in part of slag cement and ordinary sand.

QUARTERLY REPORT

ON THE

PROGRESS OF THE IRON AND STEEL INDUSTRIES

IN FOREIGN COUNTRIES.

By DAVID FORBES, F.R.S., &c.,

Foreign Secretary to the Institute.

1872.—III.

A. METALLURGICAL TOPOGRAPHY.

Annual make of Cast Iron in the World.—In order to form something like an approximate estimate of the total annual production of cast iron on our globe, the most reliable statistics of the trade have been compiled by an American metallurgist for the last year, 1871, and the result shows a total of somewhat over thirteen and a-quarter million of tons; the details of this figure being geographically as follows, the different countries being arranged in accordance with their actual production last year:—

Great Britain	6,500,000
United States	1,912,000
France	1,350,000
Germany	1,250,000
Belgium	896,000
Austria	450,000
Russia	330,000
Sweden and Norway	280,000
Italy	75,000
Spain	72,000
All other countries	200,000
	13,315,000

from which it will be seen that the annual make of Great Britain is still nearly equal to the united production of the whole of the rest of the world put together.

Africa.—Much attention is now being paid to Algeria and other parts of the north of this Continent as a source of iron ore, and the exportation of iron ore has of late greatly increased, especially to France. A memoir on the Soumah Iron Mines in Algeria, by M. C. Méne, will be found in the Revue Hebdomadaire de Chimie Scientifique et Industrielle, for May 9, 1872. These mines are readily accessible, having railway communication to a shipping port; the ores contain from 47 up to 65 per cent. metallic iron, along with some manganese, and with but very little silica.

From information derived from Sir John Swinburne, it appears that the negro tribes in the interior of Africa, some 800 miles from Natal, are extremely expert in the manufacture of wrought iron, which they smelt in little clay furnaces, from the native ores. They sell the iron thus made, which is said to be extremely good in quality, at so low a price that it is cheaper than that which is imported by the settlers at the gold mines, who consequently employ it for their implements.

Austria.—All the accounts received from this country describe the iron and steel industries of the Austro-Hungarian Empire as advancing and in a state of great activity.

The Bessemer process for steel making is rapidly gaining ground, and the new works at Zeltray, which are the largest in Austria, have now been in successful operation since April this year. In consequence of the demand for spiegeleisen, created by the rapidly extending use of the Bessemer system, much attention has of late been directed to the manufacture of this kind of iron in Austria. The Director of the Imperial Geological Institute, which, unlike our geological survey, occupies itself also with the practical questions connected with the development of the mineral resources of the empire, Herr Carl von Hauer, read at the May meeting, a report on this subject, in which it is announced that after a number of less successful experiments, the Jauerburg Iron Company, whose furnaces are situated at Jauerburg in Carniola, have succeeded in producing, on the large scale, spiegeleisen, containing more than 5 per cent. of carbon, along with from 12 up to 22 per cent. metallic manganese. When broken across, this spiegeleisen does not show so large bladed

a fracture as the Siegen metal, and is somewhat more radiating in its crystallization; it has, however, been already employed in the Bessemer steel works in Styria and Carinthia, with, it is stated, the most satisfactory results. The iron ores from which it is produced are from the mines of Belschitza and Lepene, where they occur as lenticular deposits in the triassic limestone strata, being granular carbonates of iron, which, from their being poor in manganese, require to be smelted with an admixture of richer manganese ores from other mines.

Amongst the Austrian iron companies, the dividends declared for the last year, 1871, have been—for the Wolfsegg-Traunthal Company at the rate of 20 per cent.; the Innerberg Hauptgeverkschaft, 9½ per cent.; and the Neuberg-Mariazell, 9 per cent. respectively.

The metallurgical statistics of the Austrian Empire are far behind, and it is only very recently that the official report on the mineral products of Austria proper (not including Hungary) for the year 1870, has appeared in print. In that year the quantity of iron ore raised from the mines is given at 745,620 tons, and the total quantity of cast iron extracted at 248,722 tons, of which 215,269 tons is classified as forge pig used in the production of wrought iron, and the remainder 33,453 tons as foundry pig, Of the total quantity of pig iron produced, no less than 84 per cent. was smelted with charcoal, and only the remaining 16 per cent. with coke; looking at this quantity geographically, 37 per cent. of the total amount was smelted in Styria; 23 in Bohemia; 21 in Carinthia; 11 in Moravia; and 2 in Silesia. The northern provinces, *i.e.*, Bohemia, Moravia, and Silesia, are now taking steps to increase greatly their production of iron smelted by mineral fuel; a large company is about commencing in Moravia, to smelt the iron ores from Upper Hungary, whilst the Innerberg Iron Company is about to smelt the rich Styrian ores of the Erzberg in blast furnaces at Schovechat on the Danube, near Vienna, with coal from the mines at Ostrau, in Moravia.

The well-known Austrian metallurgist Tunner has, in the Berg. u. Huettenm. Jasbuch fur der k. k. Bergakademien zu Przibram u. Lioben, given a paper on the improvements made in the working of blast furnaces in the Cleveland district in England, wherein he expresses himself strongly in favour of the increased size of the blast furnaces and of the so-called superheated blast.

It may also be mentioned that a new weekly technological journal, commencing with this year, has made its appearance in Vienna, called Der Techniker, which is intended to be a polytechnic journal, and of which we have already received several numbers.

The following works have recently been published in Vienna :—

Mittheilungen ueber das mechanische puddeln nach Danks. (Information on the Danks' system of mechanical puddling), von J. J. Bodmer, Ingenieur in London. 1 hft. Bericht der von England nach America gesandten Commission. Vien., 1872. Lehmann und Wentzel.

Friese F. M. Uebersicht der Roheisen-production der oesterreichisch-ungarischen Monarchie, nach amtlichen Quellen. (Review of the production of cast iron in the Austro-Hungarian Monarchy, from official sources.) With 9 plates and 1 map. Vien., 1870. v. Waldheim. 1 thr.

Belgium.—The state of the iron trade in this country during the last quarter may be likened to that of England. All the ironworks have been overwhelmed with orders, and have been kept in quite unwonted activity; yet the extremely high prices, not only of the product but of the raw materials, as ironstone and coke, combined with the uncertainty as to how long this abnormal state of things may continue, have combined to bring about a feverish state of excitement which is far from healthy, and which as yet has rather kept increasing than showing any tendency to diminish.

Blast furnaces, previously idle, have during the last quarter been put into operation, and new works have been erected; thus it may be mentioned that in the month of May, the Société de Couillet have blown in one blast furnace on foundry pig, as was the case also with the Société Gillain & Cie. de Châtelet, as well as the furnaces of M. Louis Dupont a Châtelineau and MM. Cambier and Cie. at La Louviére.

On the 24th May, M. E. Bonehill was authorised by a royal decree to make the following additions to his ironworks at Marchienne-au-Pont :—Eight puddling furnaces with four vertical gas generators; two reheating furnaces with two vertical gas generators; two fans for the above, worked by a ten-horse power steam engine; a ten horse-power circular saw; one reversing train of rolls for rolling girders: one large merchant train of rolls of 16·4 inches diameter; one steam engine of 150 nominal horse-power, and a two-ton steam hammer.

In the central district two new furnaces have been put into blast, in exchange for one old one blown out, and a new blast furnace, belonging to the Sociétié Michel Helson et Cie., has just been started at Hautmont, a proof of the energy of the management, since its erection was only commenced in March this year.

The firm of De Dorlodot Fréres has been converted into a joint-stock company, with a capital of £240,000, under the name of the Société Anonyme des Forges d'Acoz et Châtelineau, which commenced operations in May, with orders in hand for more than 10,000 tons of pig iron, and 50,000 tons of rails, &c.

A new company, called the Société des Forges et Laminoirs de Luxembourg, with a capital of £24,000, has also been formed.

The annual report of the Chamber of Commerce for Charleroi, for 1871, has recently appeared, and shows that, although other branches of the iron trade had been prosperous, this was not the case with the manufacture of rails, which had very considerably declined during the two preceding years, as will be seen from the following figures, which show the total exportation during ten years, and is particularly marked in the case of the exportation to Russia, the figures of which are also appended :—

Exportation of rails in	1869.	1870.	1871.
Total exportation............	136,185 tons.	124,529 tons.	81,970 tons.
Exportation to Russia alone	67,419 „	54,338 „	5,195 „

In the Charleroi district, during the year 1871, there were 13 establishments making pig iron, which employed 2,312 workmen. and kept 27 blast furnaces in work, along with 14 standing idle. The total manufactured product of the district reached 528,120 tons; the quantity of foundry pig iron being 31,520 tons, along with 327,600 tons forge pig. In the same district were in operation 21 mechanical workshops, 42 foundries with 80 melting cupolas, and 20 rolling mills, in which were 394 puddling and 162 reheating furnaces. The total number of hands employed in the iron manufacture amounted to 10,672, producing 380,157 tons cast, and 240,702 tons wrought iron, representing a total value of about £2,900,000.

On the 5th May, M. Philippart, of Seraing, at a meeting of the Société des Ingénieurs Civils de l'Ecole de Liége, communicated his report on the Danks system of mechanical puddling, the working of which had recently been studied by him in England. This report,

which was highly favourable to the system, which he regarded as a great metallurgical improvement, created much interest, and on the 16th May a conference of ironmasters was held at Namur, at which a committee of eight members was appointed to select a competent metallurgical engineer to proceed to England and report upon the process. At a subsequent meeting, M. Leopold Taskin, of Jemeppe, was appointed by the district of Liege, with whom was associated M. Tahon, of the Couillet Iron Works, nominated by the Charleroi district. These two gentlemen have lately returned to Belgium, after having witnessed the working of the Danks furnace at Middlesbrough, and attended the Glasgow meeting of the Iron and Steel Institute. It is understood that their report is also highly favourable to the system.

A meeting was convened at the Ministry of the Interior at Brussels on the 17th June, at which the Belgian ironmasters assembled, to make arrangements, that the iron and steel industries of Belgium should be represented at the forthcoming exhibition at Vienna in 1873, in a manner worthy of the country and of the high position it occupies in these manufactures. A committee was formed, and it was arranged that the iron masters themselves would defray the necessary expenses, including the decoration of their department in the Exhibition building.

The official statistics show that the imports of iron of all kinds for the first quarter of 1872 have been 47,360 tons, against 21,600 tons in the corresponding period of last year; whilst the exports for the first quarter of 1871, amounting to 56,960 tons, have during the first three months of this year reached 91,429 tons.

It is worthy of note, that amongst the exportations 400 tons less rails were sent to Germany during the first quarter of this year than in the corresponding period in 1871, and that the exportation to France was also less; whereas to England, to which country none had been sent in previous years, 1,300 tons were exported, of which no less than 1,100 were exported in the month of April, during which month alone the exports amounted to 31,054 tons, as compared with 20,093 tons in the corresponding month last year.

The latest official returns yet received by us, are the tables issued by the Finance Ministry, showing the quantities of iron and steel exported from or imported into Belgium, during the first four

months of the present year, from which we condense the following data :—

Importation of steel during the first four months of 1872, in kilogrammes :—

		Germany.	England.	France.	Netherlands.	Other Countries.	Total.
Cast steel ingot.	1872	188,395	138,554	—	—	5,832	332,781
	1871	520,236	276,518	—	—	—	796,754
	1870	335,815	—	—	—	255	336,070
Bar, sheet, and wire.	1872	619,284	2,237,786	6,767	16,044	—	2,879,881
	1871	179,065	1,263,689	3,318	1,125	—	1,447,197
	1870	268,926	843,663	11,985	6,137	2,297	1,133,008
Manufactured steel goods.	1872	124,918	433,322	69,572	161	—	629,973
	1871	46,674	180,249	11,749	—	—	238,672
	1870	55,624	136,660	45,571	213	57	238,125

Exportation of steel during the first four months of 1872 in kilogrammes :—

		Germany.	England.	France.	Netherlands.	Other Countries.	Total.
Cast steel ingot.	1872	199	110	—	—	655	964
	1871	—	29,000	—	—	1,247	30,247
	1870	—	—	—	—	—	—
Bar sheet and wire.	1872	30,315	1,700	42,177	—	100,321	174,513
	1871	2,872	113,511	3,135	—	285,496	405,014
	1870	409	1,090	13,575	—	493	15,567
Manufactured steel goods.	1872	150,552	2,783	7,022	23,197	22,384	205,938
	1871	2,910	4,164	501	5,927	90,833	114,335
	1870	4,753	—	14,776	251	18,627	38,407

The following figures show the quantities of iron ores (including filings) which were imported into, or exported from, Belgium during the first four months of the years 1872, 1871, and 1870 respectively, given in metrical tons :—

	1872.		1871.		1870.	
	Imports Tons.	Exports. Tons.	Imports. Tons,	Exports. Tons.	Imports. Tons.	Exports. Tons.
Germany	200,838	14,880	136,442	10,624	129,175	12,078
Netherlands	3,881	10,920	1,815	—	6,430	670
England	10	—	—	—	105	½
France	56,149	36,425	43,820	31,510	67,183	41,240
Spain	710	—	—	—	—	—
Other Countries	—	—	412	—	—	80
Total	261,588	62,225	182,489	42,134	202,893	54,069½

The importations and exportations of cast and wrought iron of all kinds, whether crude or worked (when converted into metrical tons), were, during the first four months of the years 1872, 1871, and 1870 respectively, as follows :—

	1872. Imports. Tons.	1872. Exports. Tons.	1871. Imports. Tons.	1871. Exports. Tons.	1870. Imports. Tons.	1870. Exports. Tons.
Russia	...	2,899	—	2,809	—	7,349
Sweden and Norway	160	120	592	9	297	10
Denmark	—	149	—	62	—	35
Germany	3,384	25,789	499	25,990	860	23,171
Netherlands	4,901	13,655	1,751	9,149	2,034	7,330
England	36,938	8,505	18,308	3,776	29,538	3,955
France	1,931	10,668	458	1,913	1,784	15,251
Italy	—	1,909	—	558	—	4,847
Portugal	—	365	—	80	—	—
Spain	—	796	—	344	—	942
Switzerland	—	3,605	—	45	—	1,463
Austria	—	9,589	—	5,622	—	807
Turkey	—	1,637	—	1,762	—	7,077
Mexico	—	459	—	—	—	—
Cuba and Porto Rico,	—	553	—	966	—	527
Brazil	—	327	—	224	—	155
Egypt	—	—	—	17	—	1,321
English Colonies	—	600	—	1	—	—
Rio de la Plata	—	205	—	495	—	48
United States	—	9,254	—	3,007	—	3,034
Chili and Peru	—	87	—	83	—	195
Other Countries	34	251	5	40	2	34
Total	47,348	91,422	21,613	56,952	34,515	77,551

Comparing the declared value of the importations and exportations of iron ores, and iron and steel of all classes, we find that there is a marked increase of value in the following instances, when the first four months of this year are compared with the corresponding period of 1871:—

	Increase on value of Imports. Francs.	Increase on value of Exports. Francs.
Iron pig and scrap	1,897,524	609,960
„ ores and filings	2,135,730	—
„ bar, including rails	—	1,740,964
„ plate and sheet	—	530,030
„ of all other kinds	—	1,676,300
„ manufactured goods	—	1,126,632
Steel bars, plate, and wire	1,790,855	—
„ manufactured goods	1,173,903	—

From the Moniteur des Interêts Materiels for the 24th August, we translate the following remarks on the situation of the Belgian iron trade at present:—"Prices have not altered except for foundry pig, which has reached 160 francs (£6 7s. 6d.) Everyone is awaiting

news from the English market, which during the last ten days has exhibited such curious fluctuations. A reaction is feared, and the slight lowering of prices has made many fearful. Little by little foreign countries are making themselves more independent of us. Austria, who with the excellent iron of her own only purchased ours because of its lower price, now finds it more profitable to utilise her Carinthian iron; Russia supplies herself from her ironworks in Siberia; and France, for the numerous works in progress, does not apply to us, so that the demand will lower itself to the production."

Canada.—An English company, under the name of the "Quebec Iron Company, Limited," was registered on the 9th August, with a capital of £90,000 in shares of £10 each, for the purpose of acquiring a freehold property of some 12,850 acres in Drummond County, Canada, abundantly timbered, and which is estimated to contain 500 tons crude or some 334 tons washed iron ore per acre, which occurs as a bed averaging about two feet in thickness, and only from one to three feet below the surface. The ore is what is called "bog" ore, a hydrated brown hematite, containing about 54 per cent. iron; and it is proposed to erect furnaces capable of producing 15,000 tons per annum, the works for so doing being only estimated to cost £10,000, which seems an extraordinarily small amount. The entire cost of manufacture, including the digging up, washing, carriage, preparation of the charcoal, and smelting of the ore, is estimated at £3 per ton. The iron produced is described as "equal, if not superior to the best Swedish," a statement rather surprising, as ores of this class usually are found to contain considerably more phosphorus than the run of the Swedish native oxides which are smelted, and which rarely contain as much as one-tenth of a per cent. of this deleterious element.

At the recent half-yearly meeting of the Grand Trunk Railway Co. of Canada, the report of the engineer stated that in the 110 miles of Bessemer steel rails which had been laid down on their line, only some eight or ten had broken, whereas of the iron rails, they were accustomed every winter to have from 3,500 to 4,000 rails fractured, a result which seems to tell greatly in favour of the employment of steel rails instead of iron in countries like Canada, where they are exposed to very low temperatures.

France.—The French ironworks are rapidly recovering their

position, and are everywhere actively occupied with an abundance of orders on hand. Notwithstanding the bad state of affairs last year, the Châtillon and Commentry Iron Works have returned a profit of £37,612 for 1871.

In the Ardennes, M.M. Mineur et Vireux have lighted a second blast furnace, which enables them now to turn out nearly 100 tons of forge pig daily. The charcoal iron trade has also been much more active in the Haute-Marne district, and in Comté several furnaces have recently been put in blast which had been long standing idle; in this district it is reported that some forty-five furnaces will soon be in operation. A new company entitled la Société des forges de la Séine, has been formed for carrying on the ironworks situated on the banks of that river near Charenton.

The Compagnie de Terrenoire in the Loire district are completing a third blast furnace intended to produce Bessemer pig for the supply of their steel works.

In 1871, the production of steel in the shape of rails, tyres, bars, &c., made by the Bessemer or Siemens-Martin process, is given at 253,662 tons, along with 841,000 tons merchant bars, rails, plates, &c., and 311,000 tons pig iron.

During the first quarter of the present year, the importation of iron ores was only 106,000 tons, as compared with 118,000 tons in the corresponding period of 1870. Almost the whole of this decrease is due to less ore being imported from Germany, as the importations from Spain are about fifty per cent. more than before, and those from Algeria are also augmented. During the first five months of 1872, the importation of iron ores amounted to 214,000 tons, against 228,000 tons in the same period in 1870. Of these amounts, Germany had diminished from 46,000 tons in 1870 to only 7,000 this year, the deficiency being, however, in greater part made up by increased importation of ore from other countries.

The following figures are from the Custom-House returns:—

IMPORTS.

	During the first quarter— 1872.	1870.	During first five months— 1872.	1870.
	Tons.	Tons.	Tons.	Tons.
Pig iron	41,000	35,000	60,000	71,000
Wrought iron	16,000	21,000	24,000	32,000
EXPORTS.				
All classes of iron, including manufactured	24,000	15,000	38,000	24,000

From the above statement it will be seen that the state of the iron trade in France is still much behind what it was before the commencement of the late war. In criticising these figures it must, however, be remembered that a large portion of the iron-producing districts of France was, at the termination of the war, transferred to Germany by the annexation of Alsace and Lorraine.

We extract the following analyses of French iron ores made in the Chemical Laboratory of the Département de Mézèires, from the report published in the Annales des Mines, 1872, I., pp. 91-96 :—

	a	*b*	*c*	*d*	*e*	*f*	*g*
Sesquioxide of iron	44·75	31·46	64·20	72·08	72·60	0·29	72·42
Protoxide of iron	0·82	—	—	—	—	47·57	—
Silica	47·98	60·00	11·42	7·60	0·25	7·10	7·87
Alumina	0·11	0·20	0·41	2·76	—	1·32	1·60
Lime	tra e	trace	5·00	0·20	7·00	7·11	0·40
Magnesia	—	—	1·08	—	0·39	—	0·05
Sulphuric acid	0·34	0·34	0·14	0·17	0·09	0·95	trace
Phosphoric acid	—	—	—	0·07	0·22	0·10	trace
Water hygrometric	1·10	2·00	3·75	1·80	2·87	0·53	trace
Water loss on calcination	4·50	6·00	14·00	15·80	16·58	35·08	17·10
	99·60	100·00	100·00	99·88	100·00	100·00	99·44
Metallic iron	31·95%	22·02%	44·94%	50·45%	50·32%	37·20%	50·70%

(*a.*) Iron ore newly discovered in the Forest of Marquisades, Commune d'Anchamps, which occurs in the Devonian slates of the Ardennes; the mineral which is called in the district "mine rouge," is a hematite, and is in the vicinity of the Vireux blast furnaces.

(*b.*) Iron ores from same place as last, called "mine jaune," which is an arenaceous yellow ochre. Neither of these ores contain either phosphorus or manganese.

(*c.*) Nodular iron ore found in the compact grey marls above the astarte limestone of the Ardennes near Bayonville, but is not abundant enough to be of importance practically.

(*d e f.*) Iron ores from the Portland limestone formation at Ancerville, smelted at the blast furnaces near Saint-Dizier; (*d*) being pisolitic limonite of a greenish yellow colour, traversed by veins of compact brown oxide; (*e*) red hydrous hematite with fossil impressions; (*f*) a carbonate of iron, which oxidises rapidly when exposed to the air.

(*g.*) Iron ore from deposits in the inferior, and great oolite forma-

tions at Cernion in the Ardennes, now used in the coke blast furnaces at Vireux. In former years, when wood was more abundant, these ores were largely used in the charcoal blast furnaces, and appear to have been employed even in very ancient periods, ruins of rude furnaces made of white quartzite being still seen, which are surrounded by great heaps of black compact, and very heavy slags, which are carted away to be smelted in the present blast furnaces at Vireux.

An analysis of these slags showed their composition to be as follows:—

Protoxide of iron	74·26
Silica	20·47
Alumina	1·50
Lime	2·25
Sulphuric acid	0·09
Phosphoric acid	0·42
	98·99
Metallic iron	57·35

In many other places in the Department of Ardennes enormous mounds of similar slags are found, which testify to the magnitude of the smelting operations carried on by the ancients in these regions. Some of these slags are not fit to be re-smelted or used for fettling, but others are largely utilised for this latter purpose, especially when employed in combination with limestone; the analysis of the ancient slags of Belval in the canton of Buzaney, which are employed in the puddling furnaces at the Flize Iron Works is here appended:—

Sesquioxide of iron	66·19
" of manganese	traces.
Silica	10·00
Alumina	1·40
Lime	5·00
Magnesia	0·50
Phosphoric acid	2·16
Sulphuric acid	0·25
Water hygroscopic	4·50
Fragments of charcoal, &c.	10·00
	100·00

The metallic iron in the above amounted to 46·33 per cent., all of it being in the state of sesquioxide, owing to the oxidation of the protosilicate of iron and the granules of metallic iron originally present in the slag.

Amongst the recent additions to the French literature of the iron and steel industries, the most important by far is the

Revue de l'Industrie du fer en 1867, par S. Jordan, Professeur de Métallurgie à l'Ecole centrale des Arts et Manufactures. 8vo, pp. 582, with 16 plates. Paris. Noblet.

This work is a continuation of the admirable Report by Professor Jordan, on the manufacture of cast iron in 1867, being one of the series of Reports published in connection with the great exposition of 1867,—the present volume having unfortunately been delayed in appearing owing to the late war in France. These two volumes are quite indispensable to all who wish to make themselves thoroughly acquainted with the manufacture of iron and steel, at home as well as abroad, and are amongst the most valuable contributions to metallurgy which have appeared in later years.

Boileau L. A. Le Fer, principal élémént constructif de la nouvelle architecture, conclusions theorique et pratique. (On iron as the principal element in modern architecture.) 8vo. E. Lacroix. 3 frc.

Clervaux, P. Metallurgie et économie industrlelle. Nouveaux procédés pour le moulage de la fonte de fer, leurs applications à la fabrication des tuyaux et des colonnes, &c. (New processes for casting iron as applied to pipes and columns.) Versailles. 1870. Duboscq et Thésé. 8vo, pp. 48.

Frontault, H. Essai sur la transformation de la métallurgie au bois dans l'Ariége. (On the changes in the charcoal metallurgy of Ariége.) Paris. Dunod. 8vo, pp. 78.

Greiner, A. Notice sur l'emploi des aciers Bessemer. (On the employment of Bessemer steel.) Paris. Lacroix. 8vo, pp. 15. 1 frc.

GERMANY.—We have not been able to meet with any statistical information showing the extent of the various departments of the iron and steel industries of Germany since it has become an empire, the latest information not extending to a later date than the year 1870, in which year the exploration of the iron mines, which were 1,275 in number, occupied 27,289 workmen, and produced a total of 3,839,222 tons (metrical) iron ores, valued at 8,037,799 Prussian dollars, or about £1,390,000. The particulars of this amount, and the quantities of iron ore extracted from the mines worked in the several countries which are regarded as forming United Germany are as follows:—

Country.	Metrical Tons.	Value in Prussian Dollars.
Prussia ...	2,676,400 ...	6,549,793
Anhalt ...	1,224 ...	3,426
Luxemburg ...	911,695 ...	920,971
Bavaria ...	97,030 ...	230,843
Saxony ...	16,011 ...	78,570
Wurtemburg ...	29,480 ...	73,927
Baden ...	84 ...	343
Hesse ...	47,163 ...	106,746
Thuringia ...	13,047 ...	27,898
Mecklenburg ...	— ...	—
Oldenburg ...	1,532 ...	1,218
Brunswick ...	45,508 ...	44,064

In Bavaria, according to the latest statistical information, 97,030 tons of iron ore were raised in 1870; and the ironworks during the same year turned out 43,968 tons pig iron, 11,633 tons iron castings, 60,278 tons bar iron, and 1,799 tons plate and sheet iron. The want of coal prevents Bavaria from reaping the full advantages from the large quantities of hematite and oolitic ores, which have to be smelted with fuel imported from Saxony or Westphalia. The largest iron works in Bavaria are the Maximilian's Huette, near Regensburg. The Kaiserlautern Iron Works paid last year, 1871, a dividend of 14 per cent. to its shareholders.

An English company, called the "Britannia Iron Mining and Spiegeleisen Company (Limited)," with a capital of £80,000 in shares of £20 each, has very recently been formed "for the development of mineral properties in Prussia;" but as yet we have no information as to their proposed plan of operations.

The papers by Funk and Wintzer, with plates of the Georgs-Marien Iron Works near Osnabrueck, which were referred to in our last Quarterly Report, have since been published, as a separate work, in Hanover; and a lengthy illustrated description of the works, extracted and translated from these authorities, will be found in the number of "Engineering" for the months of May, June, July, and August this year.

The dividends declared for the year 1871 by the undermentioned iron and steel works in Germany are stated to be as follows:—Charlottenhuette, near Siegen, 9 per cent.; Rhenish Iron Company at Duisberg, 4 per cent.; Cologne-Muesen Company, 3½ per

cent.; Tarnowitz Iron Works in Upper Silesia, 9 per cent.; Wilhemshuette, near Sprottaw, in Silesia, 8¼ per cent.; Styrum Iron Works, near Oberhausen, 10 per cent.

Several of the more important mines of iron ore, suitable for making iron for conversion into steel have lately changed ownership, Krupp, of Essen, having purchased to the amount of £550,000, which includes a group of concessions containing spathic and specular iron ores, estimated at two and a half millions of Prussian dollars, and the Eupel mine, capable of turning out 15,000 tons ore per week, and purchased for 1,200,000 Prussian dollars. The Bochum Steel Company have also acquired the Wilhelmine Kullenwald, Ecke and Wasserberg Iron Mines for, it is reported, the sum of £220,000.

In Western Prussia the following are stated to be the prices ruling in May :—

Iron ores, spathose carbonate	£1	2	5	per ton.
„ „ calcined ...	1	7	7	„
„ specular oxide	1	4	7	„
„ brown hematite	0	18	0	„
„ Nassau red do., 45 per cent. iron	0	15	0	„
Pig iron, charcoal made, grey	7	16	0	„
„ „ white and mottled	7	10	0	„
„ coke made, Bessemer ...	7	10	0	„
„ „ grey	7	4	0	„
„ „ white and mottled	6	18	0	„
„ mixed charcoal and coke made, grey	7	10	0	„
„ „ white and mottled	7	4	0	„
Spiegeleisen, charcoal made	9	18	0	„
„ coke made, No. 1 ...	9	0	0	„
„ coke made, No. 2 ...	8	11	0	„
Wrought iron, puddled bars	9	12	0	„
„ hammered bar iron	13	16	0	„
„ rolled	13	4	0	„
„ flat	13	10	0	„
„ slabs	13	10	0	„
„ wire iron	13	10	0	„
„ sheets, 1st	18	12	0	„
Steel, puddled	14	8	0	„

In connection with the subject of strikes amongst the workmen engaged in the manufacture, the German ironmasters, who hitherto have been all but exempt from this evil, which of late years has done so much damage to the British iron trade, are now beginning to feel considerable anxiety on this score, and in order to show the mode of action taken by Mr. Krupp, the proprietor of the celebrated steel works of Essen, probably the largest in the world, and employing nearly 9,000 workmen, it is thought that a copy of the circular posted up by him on the 24th July last, at the steel works, might prove interesting to the members of the Institute. The following is a somewhat free translation of this document.

"To the workmen of the Cast Steel Works.—Forty-five years ago I was myself one of the few workmen in these works, such as they then were—my patrimony. The daily wages of the smiths and puddlers had then been raised up to 9d. per day; the entire weekly pay being 4s. 6d. For fifteen years the returns from these works only enabled me to pay the men their wages, leaving me for my labour and anxiety nothing beyond the conciousness of having done my duty. With the improvements in the general state of affairs, and the progressive success of the works themselves, I made an invariable rule of gradually raising the rate of wages; never waiting to be asked to do so, but doing this of my own free will; that rule shall always remain in force. One useful institution after another has been founded, and many more are yet to come: the utmost exertions have been made to forward the interests of the workmen, and the dwellings for them now in progress may be counted by thousands. When all branches of trade were depressed; when orders were not forthcoming, I still worked on and never dismissed a single faithful servant: many old men are now here to testify to this! ask them, what was done for them in 1848? The recent sacrifices made during the years of the war are well known to you all, and who can estimate the loss caused by the present scarcity of coal. Mutual confidence has made these works great: I know that I deserve and possess your confidence, and it is therefore I address these words to you.

Before I have occasion to complain of unfaithfulness and resistance, I warn you of the fate which newspapers, and travelling agitators, who, under the mask of benevolence, make use of religious and moral quotations, are endeavouring to prepare for the working classes as a whole; their harvest commences when they have irrevocably undermined the very existence of your class. They work with all their influence for your entire destruction, so that they may cast their nets in troubled waters. Ask after the antecedents of these apostles, after their domestic and moral life; to them the contributions of the workmen for disseminating verbal and written scandal, are an easier and more pleasant mode of gaining money than is offered by honest labour. The *Essen News*, amongst others, by inventions of all kinds, endeavours to discredit the character and management of my works and to create disturbance, states, yesterday, that the conference had been coerced to agree to a considerable advance of wages for one class of furnacemen. To these, and similar broad lies of evil disposed opponents, I reply with the following warning:—Nothing—no course of events— will ever induce me to concede anything to force. The management of these works will be conducted with the same spirit of benevo-

lence which has always been regarded as a law, and in accordance with my principles, and as long as the workmen remain faithful on their side, so long shall I consider them as forming part of this establishment. I might, without doubt, transfer my interests to other parties, but I am certain that no company of capitalists would excel me either in benevolence or in willingness to make sacrifices. Nobody will believe that mere desire for gain induces me to undergo the cares and labour which the management of such a business on my own account entails. Everybody knows how I have always appreciated labour and the labourer ; but everyone may also be assured that a misconception of my sentiments would be sure to eradicate this implanted love for both.

"Be all convinced that I never waver in my resolves, and that as I have always done hitherto, I do not promise without fulfilling ! I, therefore, again warn you against the inducements to disturb quietness and peace. To every honest and orderly workman within the circle of my undertakings, after a moderate length of service, there is offered the opportunity of spending his pension in his own house, in a manner not surpassed in any part of the world. I expect and demand full confidence ; I refuse to consider any unjust demands, but I will, as hitherto, anticipate all just ones ; I request, therefore, all those who are not content with this to give in their notice of leaving ; and the sooner the better, that they may not receive notice from me. Let them leave this establishment in a lawful manner and make room for others, with the assurance that in my house and on my own ground, I am and ever will remain, master.—Alfred Krupp."

The following additions to German technological literature, as connected with the iron and steel trades, have to be noticed :—

Schinz, C. Studien ueber d. Hohofen zur Darstellung von Roheisen, Nachtrag zu d. Verf. Documente betr. d. Hohofen. (Blast furnace studies, being a supplement to the author's previously published blast furnace documents.) Gr. 8vo., pp. 112, with 23 4to. plates. Augsburg, Cotta. 1871. 18 sgr.

Heim, G. Tabellen u. d. Gewichte von Rundeisen. Wellen, Flacheisen, Eisenblech, Ischmied u gusseiserne Rohr. (Tables showing the weight of round and flat iron, plates, tubes, &c.) 16mo., pp. 14. Stuttgart. Wittever. 3 sgr.

Kustermann, F. S. Querschnitte d. Stabeisen-lagers u. Federstahl. (Sections of iron and steel.) Folio, 12 chromolithograph plates. Munchen, Finsterlin. ⅔ th.

Funk, W., Wintzer. Die Georgs, Marienhuette bei Osnabrueck. (Description and drawings of the Georgs-Marien Iron Works.) 17 plates, and woodcuts in text. Hanover. Schmorl u. v. Seefeld. 5 th.

Petzholdt. A. Fabrication, Pruesfung und Uebernahme von Eisenbahn-Material. (The manufacture, testing, and overtaking of railway materials), with 27 plates and 254 woodcuts, pp. 207. Wiesbaden, Kreidal, 1872. Gr. 8vo. 4 thalers. A well illustrated work, which can be recommended as containing a large amount of information connected with the manufacture of iron and steel for railway purposes, in a condensed and extraordinary cheap form.

Dr. Drouns paper, on the Attainment of Uniformity in Bessemer Steel, has been translated into German, and will be found in the Berg u. Huettenm, Zeitung, for May 10, 1872.

INDIA.—A deposit of iron ore is reported as occurring in the Hazareebaugh district, and to extend over some five hundred square miles of country. It is stated to contain 70 per cent. of metallic iron, along with a little manganese, and as it is not far from the Damooda coalfield, the discovery is supposed to be very important. Discoveries of iron ore, said to be of good quality, are also announced from the Kuramam district of the Nizams territories, and specimens have been sent to Hyderabad for examination.

With reference to the wrought iron pillar at the Mosque of the Kutub at Delhi, alluded to in the first quarterly report for this year, Lieutenant Spratt, of the Royal Engineers, then stationed at Delhi, has kindly, in answer to our inquiries, procured on the spot some information, which enables some of the statements as to its dimensions to be corrected; according to these data, the height of the column above ground is only 24 feet, and 3 feet below ground it ends in a bulb like an onion, which is held in its place by eight short thick rods of iron, on which it rests, and which at their lower extremity are let into blocks of stone, in which they are secured by lead. The iron of which it is made, which appears to have been originally in blooms of about 50 lbs. weight each, has been examined by Dr. Murray Thomson, of the College at Roorkee, who found it to be wrought iron, possessing a specific gravity of 7·66. Although these measurements greatly reduce the reported size of the column, it still remains equally difficult to explain the mode of its manufacture in so early a period.

JAPAN.—In the first quarter's report for this year, a mention was made of the process of iron smelting in Japan, in which large blooms of wrought iron, weighing above 1,300 lbs., were produced direct from the ore by a sort of magnified Catalan process; from the same informant, M. Sevoz, it appears that the iron ore employed is a ferruginous black sand, washed out of the decomposed granites, which is a mixture of 90·3 per cent. magnetic oxide of iron, attracted by the magnet with 9·7 per cent. of nonmagnetic titanoferrite or ilmenite. The ore, as washed previous to smelting, affords 61·5 per cent. cast iron; the iron produced costs about £8 per ton, the charcoal being only estimated at from 6s. 6d. to 7s. per ton. The slag produced along with the bloom is very rich in iron, containing, according to M. Sevoz's analysis—

Silica	28·50
Alumina	8·37
Oxide of iron	62·25
Lime	1·74
Soda	2·13
	101·00

In M. Savoz's report to the Japanese Government, he recommended the erection of a small blast furnace, and some Franche-Comté hearths, for making wrought iron, estimating that, including repayment of the capital in five years, the iron would not cost above £4 per ton, or one-half the present cost.

We understand, however, from more recent accounts, that the attempts which have been already made to smelt these sands in a blast furnace have proved unsuccessful.

New Caledonia.—As a curiosity, it may be mentioned that the chief of the scientific department of the French Exploring Expedition in the Eastern Seas, reports that the interior of Owen Island, which is only separated from New Caledonia by the narrow but deep wooden channel, is almost entirely composed of iron ore, usually of a spheroidal form, and forming occasionally large table-lands several thousand yards square, which, when acted upon by the rain, leave gigantic conical mounds of iron ore, such as the cone of Mamié, seen on the north-east of the island. Few plants grow on this metallic soil, and as yet it does not appear that the iron ore has ever been utilised by the inhabitants.

New South Wales.—We are not aware of any works in which iron is smelted from its ores being in successful operation in any part of Australasia, although some attempts have been made in New Zealand as well as New South Wales. A recent communication from the latter country states that the Fitzroy Iron Mines, on which more than £150,000 had been expended without adequate returns, have recently been sold to an English company, which proposes to put them in immediate operation, and to erect blast furnaces for smelting the ore, which is said to be very rich in iron, and in great abundance.

Norway.—At this year's exhibition, at Copenhagen, the iron manufactures of this country play a very insignificant part, none of the few remaining charcoal blast furnaces being represented, and

the whole interest of this department being concentrated in the products of the cast steel works from the Naes and Egelands Iron Works belonging to Messrs. Jacob Aal & Son. Besides a very fine show of cutting tools of all descriptions, the finish of which left nothing to be desired, these works displayed a series of cast steel cannon of various calibres, such as are used in the Norwegian mounted artillery, one of which, after having resisted the most severe tests, when subsequently burst on purpose to examine into the effects of such treatment, merely showed a split along one side of the bore for about two-thirds of its length without detaching a single fragment or splinter, thus fully proving the admirable quality of the steel for this purpose. The cast steel made at the Naes Works is all on the old English system of first converting the bar iron into blister steel, and then smelting this into cast steel in crucibles.

The titaniferous iron ore mines of Soholt and Solner near Aalesund, on the west coast of Norway, which have for many years been in the market, have been taken over for the immense sum of £60,000 (one-half in shares of the company) by a new English company, with a capital of £100,000 in shares of £10 each, entitled the "Northern Titanic Ore and Smelting Company, Limited," which, among other objects, proposes to smelt these ores with coke on the banks of the Tyne. The ores are said to contain 43 per cent. metallic iron without any sulphur or phosphorus; both these elements were, however, found in appreciable quantity in samples of the ore sent to the author of this report direct from the mines. The quantity of available ore in these deposits is certified "to the extent of millions of tons," by a Mr. H. Brinchmann, whose report is appended to the prospectus, in which he is described as "Resident Government Engineer at Aalesund." Enquiries made in Norway have been answered to the effect that the said gentleman is not a mining engineer, and that there is no resident government engineer in that town. It may also be mentioned, upon the best authority, that the results of several years smelting of Norwegian titanic iron ores in the Norwegian Titanic Iron Company's blast furnaces at Norton, near Stockton-on-Tees, do not in any way warrant so low an estimate of the cost of smelting such ores in England as is particularised in the prospectus of the above company.

Russia.—An English company, entitled the "Finland Charcoal

Iron Works Company, Limited," with a capital of £50,000, has recently been brought before the public, with the object of purchasing an estate at Uleaborg, in Finland, in order to carry on iron smelting there for the production of charcoal iron.

The manufacture of cast steel at the Government works at Perma and Obouchow is progressing satisfactorily, the cannon made from the Russian cast steel being affirmed to be more sound and durable, as well as less liable to burst than those made by Krupp. At present the Perma foundry is engaged in casting 26 9-inch and one 11-inch steel mortars, whilst Obouchow has in hand 32 9-inch steel coast guns, all for the Russian Government.

The well-known Austrian metallurgist, Tunner, has published his report on the mining and metallurgical industries of Russia, with special regard to iron: Tunner, P. Russland's Montan-Industrie insbesondere dessen Eisenwesen, 5 plates, pp. 207, 8vo. Leipzig. Felix. 3⅓ th.

SPAIN.—A new English company, called the "Somorostro Iron Ore Company, Limited," with a capital of £200,000 in shares of £50 each, has recently been formed for acquiring and working the Mora la Union, Malaespera and Julia Iron Mines, and the lease of the Ollargan Iron Mines, situated near Bilbao, in Spain. Some of these mines, at least, produce iron ore very different in character, and are located in quite another district from that in which the well-known Somorostro Red Hydrous Hematite Mines are situated. Another English company, called the "Cantabrian Iron Company, Limited," was registered on the 15th August, the specified object being to carry on mining and smelting operations in Spain, with a capital of £60,000 in shares of £100 each.

It is also rumoured that an English limited company is about to be formed for the purchase of the old charcoal-iron works at Sargedelos, in Galicia, known as the Royal Sargedelos Foundry and Iron Works, along with certain concessions of iron ore situated at Ferrol and Pontevedra, from which it is proposed to export iron ore to England and other parts of the Continent.

SWEDEN.—The greatest excitement prevails in all the iron-producing districts of this country, the ironmasters everywhere exerting themselves to their utmost to increase their turn-out, in order to reap the benefits of the present extraordinary high price of iron; so that the total production of iron in Sweden this year will be

even in excess of what it was in 1871, notwithstanding that the make in that year was larger than in any previous one. New charcoal blast furnaces and Bessemer works are being erected on all sides, amongst which may be mentioned two blast furnaces with Bessemer works and rolling mill at Bongbro, near Nya Kobberberg, two blast furnaces with Bessemer works at Bjorneborg, one blast furnace near Linda, now finished, Bessemer works at Stjernfors and Nyhammer, the latter having been recently put in operation,—the Bessemer process being now everywhere adopted in Sweden, the cast iron being tapped into the converter direct from the blast furnace, and, as a rule, blown without the addition of spiegeleisen. A number of samples of Bessemer steel from different works in Sweden are exhibited at the Exposition at Copenhagen, and amongst some extremely fine specimens are shown Herr. Chr. Aspelin from the Fagersta and Westanfors Works. In the same Exhibition, the Finspong and Ankarsrum Iron Works, so long known for their cast iron cannon and projectiles—a branch of the trade in which these establishments have long and justly been celebrated—show numerous samples of their iron and projectiles, as well as a perforated armour-plate to show the effect of their projectiles.

In Sweden, the production of what is called cannon iron, or cast iron specially made for casting artillery from, is now confined to two ironworks—Finspong and Ankarsrum—in both of which the iron is made from the same raw materials and in precisely the same manner; the latter of these works, however, only manufactures projectiles, whilst Finspong, in addition, is well known for its cannon foundry.

The iron ore from which the cast iron intended for founding cannons is smelted, is a mixture of native magnetic oxides of iron from three different mines called respectively the Foerola, Nartorps, and Stenebo mines. In this mixture 80 per cent. of the Foerola ore, which has been celebrated and employed in Sweden for this purpose during the last three centuries, is smelted along with 10 per cent. of each of the two other ores, with charcoal, using cold blast, and is tapped into pigs, which are carefully assorted according to their hardness into ten classes, a test-bar, two feet long and three inches in diameter, being cast along with each tapping, and the degree of hardness estimated from the

appearance of its fracture,—which in Class I. is altogether dark and pretty strongly graphitic, whereas No. X. is perfectly white without a trace of graphite.

The pig iron is re-melted in reverbatory furnaces, and the classes employed, both for cannons as well as projectiles, are usually Nos. 3, 4, and 5—occasionally No. 2, but never higher than No. 6.

The specific gravity of the iron (taken from the test-bars) of the classes employed for cannons and projectiles varies between 7·30 and 7·45, that of the iron in the cannons after casting from 7·22 to 7·30; but the specific gravity of some of the projectiles which are cast in chills can rise as high as 7·65. The chemical composition of the cannon iron after re-melting in the reverbatory furnace is as follows:—

Iron	95·68
Carbon, combined	1·41
„ graphitic	2·05
Silicon	0·48
Manganese	0·25
Aluminium and calcium	nil.
Copper	trace.
Sulphur	0·13
Phosphorous	trace.
	100·00

Two rings of the cannon iron are exhibited, which show that the metal has an amount of elasticity in itself which is something extraordinary for cast iron.

All cannons of the size of 5 inches (about 24-pounders) and larger calibre are cast at Finspong, using a rising and rotating stream of metal and having a hollow core, kept cool by a stream, first of water and subsequently of air; smaller cannon are usually cast from above, and massive throughout. Along with each large cannon a smaller one of from 4 to 6 lbs. calibre is cast at the same time, whereby the quality of the larger piece can be comparatively ascertained.

The pointed conical or ogival projectiles for use against armour plates are cast with the lower or cylindrical portion in moulds of dry sand, whilst the upper or point is in iron chills. These projectiles have, upon trials made in Sweden, Denmark, and

Holland, perforated armour of 8 inches massive and $14\frac{1}{2}$ inches combined iron plates respectively, besides the oak backing of some 18 inches thick and an inner iron plate lining.

The total exportation of iron and steel from the port of Gothenburg during the first six months of the last three years is given from the Custom House returns as follows :—

1872.	First half-year,	728,523·97	Swedish centners	= 30,355	English tons.
1871.	"	808,809·98	"	= 33,700	"
1870.	"	922,572·00	"	= 38,440	"

A comparison of the above figures shows a very great falling off in the quantity exported from Gothenburg, from which it is forwarded chiefly to the English and French and American markets. This diminution is not, however, due to any decreased production, but is owing to the higher prices obtainable of late in the Eastern or Russian market, as well as in the greatly increased home consumption in Sweden.

United States.—On the 8th May, the National Association of Bar Iron Manufacturers met at Pittsburg, on which occasion the title of the Association was altered to that of the National Association of Iron Manufacturers, and the membership was thrown open to all classes of iron rolling mills. Some minor improvements in iron making were submitted to the meeting, and a favourable opinion was pronounced on Baynton's rotary puddling furnace, a description of which will be found in the *Iron and Coal Trades' Review* for April 24th, 1872, p. 327; and on the 10th, the Eastern ironmasters visited the works at Pittsburg, at the invitation of the Western Association.

The American Pig Iron Manufacturers' Association held a meeting at Cleveland, Ohio, on the 27th June, under the presidency of Mr. A. B. Stone, formerly vice-president, but who was at this meeting elected president in the place of Mr. David Thomas, who had resigned; Mr. Thomas Dunlop, of Philadelphia, was also elected secretary.

From the statements made at this meeting, it would appear that all the new furnaces in course of construction, even if now in full blast, could not meet the requirements of the increasing demand, so that the idea of America supplying England with iron, which has of late been a favourite topic in the States, may be regarded as at least somewhat premature. The general adoption of the ton

of 2,000 avoirdupois lbs. for all transactions in iron throughout the United States was urged at the meeting, but final action was postponed until October, to which month the present meeting was adjourned, the place of meeting to be Pittsburg.

The total production of rails in the United States during last year is now estimated at 775,733 tons, of which amount 715,691 tons were of iron, and 60,042 of steel or steel-headed rails. The production during 1871 in each separate State is stated to have been as follows:—Pennsylvania, 335,604 tons; Illinois, 91,178 tons; New York, 87,022; Ohio, 75,782 tons; Maryland, 33,941 tons; Wisconsin, 28,774 tons; Massachusetts, 28,864 tons; Michigan, 14,000 tons; Maine, 13,383 tons; Indiana, 12,778 tons; Tennessee, 9,667 tons; Missouri, 8,200 tons; New Jersey, 6,700 tons; Kentucky, 6,000 tons.

From all districts accounts come to hand, either of new works being erected, or old ones being extended. Amongst these we have to note in Pennsylvania that the Pittsburg Forge and Iron Company are enlarging their works at Wood Run; the mill of Messrs. McKnight and Co., of Pittsburg, which was burnt down this spring, is now entirely re-constructed and again started at Milton, Pa. The Milton Iron Company have started a new rolling mill, with three trains for merchant bars and angle iron, and another rolling mill is being erected at Leechburg. The National Iron Company at Danville have blown in a furnace, another is to be erected at Newcastle, and the Warwick Iron Company, with a capital of £40,000, has been formed for working blast furnaces at Pottstown.

In Ohio, several furnaces have been put in blast near Ironton; and at Columbus the Franklin Company has been formed, with a capital of £50,000, to erect a blast furnace and rolling mills, and the Etna Iron Company, in Pease township, Belmont County. The Otis Iron Company have ceased operations, having sold their blast furnace and forge for the sum of £125,000; the former to the Jackson Iron Company, and the latter to the New Lake Erie Iron Company. The towns of Sandusky and Toledo, in Ohio, being both desirous of becoming centres of the iron trade, have offered to the large establishment at Portsmouth, who are contemplating removal to a more favourable locality, the former the loan of £40,000 for fifteen years, if they will select Sandusky, whilst Toledo also has offered a loan of £10,000 for fifteen years. At the same time, it is

rumoured that Messrs. Gaylord & Company propose erecting blast furnaces at Sandusky, on the banks of Lake Erie, and that they intend removing their rolling mills, now at Pottstown, to that locality.

In Wisconsin, at Milwauki, Messrs. Groves are building two rolling mills and a foundry, whilst at Caseville, in Michigan, a large blast furnace has been erected by a company with a capital of £20,000.

In the South, at Wilmington, the inhabitants are so desirous of having the manufacture of iron established in the district that they offer twenty acres of land and £5,000 in cash to the first party who will erect blast furnaces or rolling mills amongst them.

In Tennessee, the Roane Iron Company, at Chattanooga, are putting up a blast furnace, calculated to run out 25 tons of pig daily, and the *Iron Age* states that Messrs. Garrison & Company, of Pittsburg, are now making for the Abbot Iron Works, at Baltimore, the largest train of rolls ever made or used as yet in the States, being 31 inches in diameter, and 8 feet in length between the bearings.

From Missouri, we hear that the Missouri Iron Company has been formed for the manufacturing of iron and steel, with a capital of one million dollars or £200,000; also that the La Grange Iron and Steel Company are erecting works at La Grange for rolling iron and steel rails, which, when complete, will contain six puddling furnaces with Siemen's regenerative furnaces, &c., calculated to turn out 5,000 tons of rails per annum, the cost of the works being estimated at £28,000. At South St. Louis, several blast furnaces are to be built, estimated to make 700 tons pig iron each per week; the first of these is to be put in blast on the 1st February, 1873. It is also stated that an English company are now constructing the blast furnaces, along with a rolling mill, about fifty miles from St. Louis, to smelt the hematite iron ores of the district, which are stated to be extremely cheap, as is also the coal, which is below 16s. per ton.

At Buffalo, New York, two blast furnaces have been blown in, and a third will be shortly in operation at the Union Iron Company's Works; and it is reported from Hudson, New York, that the adoption of a sort of hood, closing the mouth of the blast furnace, bolted fast to the tunnel head, has increased the yield of

the furnace by about one-fourth, and at the same time lowered the consumption of coal from 35 cwt. to 28 cwt. per ton of iron produced.

In Indiana, a company with a capital of £50,000 has been formed for erecting a blast furnace at Shoals, in the centre of the iron and coal districts of Southern Indiana; and another company at New Albany, for developing the iron and coal mines of Menton County. In Clay County, Indiana, according to Dr. J. W. Foster of Chicago, there are five blast furnaces all worked with hot-blast, of which the following are the dimensions and other details:—

Location	Brazil.	Brazil.	Knightsville.	Planet.	Vigo.
Name of Furnaces	Lafayette.	Brazil.	Knightsville. (2 furnaces)	Harmony.	Torre Haute.
Year of construction	1869	1867	1867-68	1867	—
Cost of construction	£14,000	£30,000	£32,000	—	—
Height of furnace	45 ft.	60 ft.	50 ft.	40 ft.	50 ft.
Diameter at boshes	10½ ft.	14 ft.	12 ft.	10½ ft.	12 ft.
,, ,, hearth	4 ft.	5 ft.	6 ft.	4 ft.	—
,, ,, tunnel head	5 ft.	6 ft.	4½ ft.	—	—
Daily consumption of fuel	45 tons	70 tons	100 tons	40 tons	—
,, ,, ore	37½ ,,	45 ,,	60 ,,	25 ,,	—
,, ,, limestone	10 ,,	16 ,,	24 ,,	10 ,,	—
Daily make of iron	18 ,,	28 ,,	45 ,,	15 ,,	20 tons

With regard to the steel manufacture, it is announced that a small steel works has been erected by the Sheffield Iron and Steel Company, at Florence, Massachusetts (with a capital of £6,400), to work a new American patent for converting iron into steel, the commencement being on a small scale, with fifty men.

The Bessemer process is, however, everywhere in the States taking the lead of all other systems for steel making. At Sharpsville, in Pennsylvania, new Bessemer steel works and a rolling mill are proposed to be erected, the Bessemer pig iron to be reduced from the Lake Superior ores. At Joliet, in Illinois, about 32 miles from Chicago, Bessemer steel works, with two five-ton converters, are in progress of construction, and a steel rail rolling mill, capable of rolling 100 tons per day, and provided with Siemens's furnaces for reheating the ingots, is to be added. The Bessemer pig is to be furnished from two blast furnaces, 75 feet high and 20 feet diameter across the boshes, each estimated to turn out 400 tons Bessemer pig iron per week, the ores smelted being from Iron Mountain and Lake Superior.

On the future of the Bessemer steel manufacture in America, Professor J. W. Foster expresses himself in the *New York Tribune* as follows:—"As the Bessemer process is destined to confer substantial benefits on mankind, and as our own country affords unsurpassed facilities for its full development, I deem it opportune to state how far it has become domiciled among us, and what expense attends its introduction. The plant necessary to produce 100 tons of ingots in a period of 24 hours costs 300,000 dollars (£60,000), and to duplicate this plant under the stone shelter costs 200,000 dollars (£40,000). A rail mill to consume this combined product costs 300,000 dollars (£60,000). Thus, to carry on the various processes from the crude material to the merchantable rail, requires a capital of not less than 800,000 dollars (£160,000). This sum may seem startling, and, yet while capital is cautious, it is ever known to seek the more profitable investments. Bessemer works have already been established at the following points: Troy, NY.; Johnstown, Harrisburg, and Bethlehem, Penn.; Cleveland, two establishments; Chicago, two; Joliet, Ill., one now erecting. Each of these establishments has a double plant, and is capable of supplying a rail mill. At Troy, the melt consists of two-thirds English pig and one-third American charcoal pig. At Harrisburgh and Bethlehem, anthracite iron, without the addition of charcoal iron, is employed. At Cleveland, pig iron from Missouri Iron Mountain ore, smelted with Brazil coal; and at Chicago, Brazil pig and Grand Tower pig made from Missouri ores, reduced from a mixture of Murfreesboro coal, two-thirds, and coke one-third, are successfully used. Mr. Holley prefers, however, in all cases, an admixture of one-third charcoal pig.

The distinctive qualities of pig metal, whether made from specular or hematite ores, are disregarded, the main features being their freedom from sulphur and phosphorus. The cost of spiegeleisen from Germany is 58 dollars gold (£11 12s. 0d.); that of the New Jersey Franklinite, about the same. The latter is richer in manganese, and is equally esteemed. There is a loss of 14 or 15 per cent. of pig metal in the conversion into steel. The scraps are utilised by drawing them into merchant bars, tyres, wire, &c. Where the cost of pig is 40 dollars (£8) a ton, ingot steel will be 61 dollars (£12 4s. 0d.), and rails, 81 dollars (£16 4s. 0d.) For these practical details I am indebted to Mr. Holley, a gentleman of

eminent experience, and under whose supervision several of the works enumerated have been erected. This branch of iron industry is yet in its infancy, and especially in the States bordering the Ohio Valley. The cardinal fact is now demonstrated, in the daily product of blast furnaces and converters, that the specular ores of Lake Superior and Missouri, by reason of their richness and purity, and the block coals of Indiana, in their near approach to charcoal as a reducing agent, and the facilities which exist for bringing these together, are destined to answer the world's imperative demand for cheap steel. It requires no prophetic vision to foresee, that before the lapse of half a century, the block coal region of Indiana will be the principal seat of the Bessemer steel manufacture, not only of this country, but of the world."

Attention is now being directed to the large deposits of iron and coal which exist in the State of Alabama; a lode of pure hematite, some 20 feet wide, is stated to run along the entire Red Mountain Range on the eastern side of Jones Valley, which is 100 miles long. This great bed of iron ore is close to the Cahawba coalfields, and the iron ore and coal will be brought into direct and easy connection with Nashville and Cincinnati by the Louisville and Southern Railway, which will be completed this year.

The existence of magnetic iron sands, some of which contain as much as 50 per cent. metallic iron, on the shore, within 40 miles of San Francisco, in immense quantities, has recently been communicated to the California Academy of Sciences.

To American metallurgical literature must be added:—

Gruener.—The manufacture of steel, translated from the French by Lenox Smith, with an appendix on the Bessemer process in the United States by the translator. Illustrated by lithographed drawings and woodcuts. 8vo., cl. pp. 196. New York. 18s.

B. METALLURGICAL TECHNOLOGY.

Composition of Crystallized Cast Iron.—Rammelsberg has lately in the "Ber. d. Deutsch. Chem. Ges., 1872, p. 430," published the results of his analyses of two specimens of crystallized cast iron which are as follows:—

(*a.*) Grey cast iron crystallized in regular octahedrons, being found in the centre of a broken roll employed for rail rolling at the

Henrichhuette at Hattingen; its specific gravity was found to be 7·255, and it contained—

Metallic iron	... ...	95·225
Carbon graphite 1·121 } „ combined 1·963 }	... ...	3·084
Silicon	... ...	1·537
Sulphur	... ...	0·113
Phosphorus	... ...	0·041
		100·000

(*b.*) White radially crystallized cast iron from Freisenburger Furnace (Neuschottland) having a specific gravity of 7·617.

Carbon	... ...	2·820
Silicon	... ...	0·334
Phosphorus	... ...	0·086
Sulphur	... ...	0·000
Metallic iron	... ...	96·760
		100·000

The carbon in this case was all in a state of combination, excepting a trace of graphite, but the author remarks that graphite is not always absent in white cast iron, as in the spiegeleisen from Madgesprung he found 16·5, and from Löhhuette nearly 28 per cent. of the entire carbon present to be in the graphitic form.

Analysis of White Pig Iron and its Slag.—From the Berg and Huettenmännisches Jahrbuch der K. H. Bergakademien Zu Przibram und Leoben, Prag., 1872, we extract the following analyses of the white pig iron and slag produced along with it from the Neuberg blast furnaces. The analyses are by Von Eschka, v. Lill and Modes.

White pig iron—

Metallic iron	... ...	94·300
Carbon (combined)	... ...	3·123
Silicon	... ...	0·616
Phosphorus	... ...	0·036
Sulphur	... ...	0·045
Manganese...	... ...	1·820
Copper	... ...	0·155
		100·095

Blast furnace slag produced along with the above—

Silica	43·70
Alumina	10·40
Protoxide of iron	0·13
„ manganese	5·10
Lime	23·54
Magnesia	13·17
Potash and soda	2·22
Sulphide of lime	1·24
Phosphate of lime	0·078
	99·578

The ratio of the oxygen in the silica to that of the bases as shown in the above analysis is as 23·31 to 18·40, and the comparison of the two analyses is interesting as showing the great proportion of the manganese which is carried into the slag when white iron is produced, as compared with the much lesser percentage reduced into the pig iron.

PEAT AS FUEL IN BLAST FURNACES.—Sometime back we informed our readers that the employment of peat as a substitute for charcoal was contemplated, in the iron blast furnaces at Ishpeming, in the Lake Superior district; the experiment was tried in the spring of this year, and is found to be, according to the "American Manufacturer," a complete success, the iron made with the aid of this combustible being represented as of excellent quality, and quite equal to what was produced, in the same furnace, by charcoal. The peat is ground wet in ordinary pulping mills, and then spread upon canvas frames to dry in the air under sheds or assisted by artificial heat; when dry, it is found to be compact, solid, and uniform in character, and is then broken up, which is easily effected, owing to parallel scores having been made in the layers whilst still moist. It is then put into sheet-iron cylinders or carbonisers of a capacity of 7 bushels each, closed at one end, and having a lid capable of being fixed down air-tight at the other. These are then put into a brick stove on the level of the top of the blast furnace, and heated by the gases therefrom (the mouth of the furnace itself being closed by a bell) for about two hours and a half, after which they are charged directly into the blast furnace along with the ore. The charred peat thus made evolves much more gas than the charcoal. The

number of such carbonisers in use for one blast furnace is 108, one half of which are kept constantly in the charring stove at the mouth of the furnace.

At Marquette, in Michigan, experiments have also been made recently in a furnace belonging to the Lake Superior Iron Company, where it is reported that the furnace, after being started with charcoal, had gradually quantities of dry peat added to the charge, until the proportions were as three quarters of peat to one quarter of charcoal; the result is asserted to be excellent, and the iron quite equal to that produced from charcoal alone.

CHEMICAL CONSTITUTION OF SLAGS.—A paper on this subject—"Molecular-Formeln der. Schlacken," by Professor A. Kerpely, of Schemnitz, will be found in the Berg w. Huettenm. Zeitung for 14th June. It is a purely theoretical communication, and although of much interest as such, could not be abstracted in the space at disposal in our report; and for the same reasons we must refer to the original for a reply to Professor Kerpely's paper, which appeared in the Number of the same Journal for 26th July, from Dr. W. Hampe, of Clausthal.

UTILISATION OF BLAST FURNACE SLAGS.—A communication on this subject, made by Mr. T. Egleston, to the American Institute of Mining Engineers, will be found reprinted in "Engineering" for 26th July this year, which gives a very good historical sketch of the subject, and to which we would refer. Of late, in Prussia, the slag, after having been granulated in water, as described in a former report, is mixed with lime or cement, and moulded into bricks, which harden on exposure to the air, and are employed in building. A patent for this system of utilising blast furnace slag has recently been taken out in England by F. Lurman, of the Georg-Marien Iron Works in Prussia.

In Sweden and Norway, nearly the whole of the slag from the charcoal blast furnaces is cast in iron moulds, and the bricks thus formed sold for building purposes,—so that the slag actually becomes a source of revenue to the ironmaster. Although somewhat brittle, and not able to sustain long transport in carts, these bricks, when once built into a wall, form an excellent building material.

RE-MELTING PIG IRON.—A modified form of cupola has been recently brought forward by Mr. Henry Krigar, of Berlin, which

appears to have decided advantages over the ordinary cylindrical cupola used in foundries, and especially so for melting iron for supplying Bessemer converters, steel, or puddling furnaces, &c., where it is desirable that the cast metal shall be run out in as clean a condition as possible. In Krigar's cupola, instead of having the lower part, sump or crucible, of the cupola immediately below the shaft of the furnace, it is placed on one side of it, connected by an inclined canal about three inches high, six or eight inches long, and as wide as the cupola itself. As this receptacle for the molten iron is only accessible to the thoroughly melted iron or slag, and does not allow of half-melted lumps of iron from above falling into it, or of the iron in it being affected by the prolonged blast, or by impurities in the coke, which in the ordinary cupola rests upon its surface, the advantages of this arrangement are self-evident.

Chilled Cast Iron Railway Wheels.—In making these wheels, which are so much used abroad, especially in the United States, Mr Hamilton, of the Ramapo Wheel and Foundry Company, instead of employing the particular brands of iron in general use for such wheels, adds a certain amount of scrap steel to ordinary pig when melting it in the cupola, and finds the resulting metal to possess an increase of from 20 to 50 per cent. in strength. Messrs. A. Whitney & Sons, of Philadelphia, are stated to have practically tested the utility of this process, by having made some 15,000 wheels in this manner during the second quarter of this year; for other castings where extra strength is required this system has long been in use in Europe.

Conversion of Cast into Wrought Iron.—A modification of the Ellershausen process has recently been patented by a Mr. Z. S. Durfee, of New York, the only difference being that the cast iron runs into an annular trough through several spouts converging to a common centre, at which point or focus the ore is introduced through a hopper, and thus becomes more intimately mixed with the molten metal, the conglomerate (as it is called) thus produced falling into ingot moulds, and being subsequently treated in a reverbatory furnace. However correct this system may be theoretically, there are so many difficulties connected with its being worked practically, as to leave but little hopes of its proving successful on the large scale.

Puddling Furnaces.—At a number of forges at Pittsburg, in Pennsylvania, the puddling furnaces have been contracted about thirty inches in length, by shortening to this extent, and so almost doing away with the neck or flue which enters the stack, an alteration which is there considered an improvement. Water-flues for puddling purposes, on the Ross and Clemens patent, are coming into general use in the United States, having been already adopted in some 210 furnaces.

Puddling by the Furnace Gases.—In the charcoal iron furnaces in Carinthia, in Austria, the puddling has for some time back been carried on without other fuel than the gas from the blast furnaces, whereby it is stated that an economy of between £2 and £2 10s per ton of bar has been secured. In this direction also the *Bulletin de Comitè des Forges* reports in favour of a new process by MM. Combescot and De Langlade, who employ the gases in a kind of regenerative Siemen's furnace, which enables the temperature, pressure of the gases, and the duration of the flame to be perfectly regulated.

Dephosphorising Iron in Puddling.—Dr. T. Scheerer has brought before the public a new process for separating phosphorus from the iron during the operation of puddling, using the chlorides of calcium and sodium; and although we have not as yet received details of the mode of working, it is said that the results obtained have proved that a very good and fibrous bar could be obtained from pig iron containing phosphorus which, in the ordinary system of puddling, was unfit for making bar iron. The amount of chlorides to be added in puddling depends upon the amount of phosphorus in the pig, and is given at three times the weight of the phosphorus to be removed. Dingz, Polytect Journal, 2nd June, 1872.

Rolling Iron.—Mr. Asa Johnson, of New York, has invented a new system of rolls for working iron, of which the following rather confused description has been published; the surface of the one roll being smooth whilst the other is studded over with protuberances. The rolls have an inner solid or tubular cylinder with an outer shell composed of removable segmental plates, the convex surfaces of which are studded with the projecting heads of rivets whose shanks pass into the plates themselves. The rolls have an interior tube of sheet metal corrugated longitudinally, an exterior shell of plain metal, and an intermediate cylinder of cast metal. The journal

bearings of the hollow rolls have a connecting tube. The hollow cylinders are cast around a sheet metal cylinder filled with water on inside, and outer tube also surrounded by water. With the hollow journal the inventor combines a metal head, a bisected sleeve and tube provided with collars, and is combined with a grooved head and slotted standard. For adjusting the rollers there are a screw, screw sleeve, flange, washer, key, and wheel. The wheels are enclosed in a casing, and steam applied to the outside of the same, an adjustable triangular block being arranged between the wheels to divide the steam. He uses a boiler provided with a flange and screw threads at each end in combination with heads having on their inner sides an inner and an outer screw flange, a central tube being screwed into the heads of the boiler, to which a safety-valve, with a slotted tube, a grooved seat, and a screw cover is applied. The inventor also uses an auxiliary boiler provided with tubes connecting the hollow rollers, and with the main boiler.

Russian Sheet Iron.—The mode of making sheet iron of this character, devised by Mr. Rodgers, of Apollo, Pennsylvania, United States, is described as follows: A pack of some forty sheets; one a-top of another is formed of interstratifying sheets of iron, of a proper gauge, with particles of charcoal of about the size of a grain of corn, taking care to spread these particles quite evenly over each sheet so as to cover its entire surface. The edges of this pack are then cleaned in the usual manner, and the whole placed in the heating furnace, resting upon a bottom plate. Round the edges of this pack a wall is piled up of wood, thoroughly saturated by soaking in water, after which the mouth of the furnace is closed tightly, and a wood fire is lighted on the grate. As soon as the fire is fully ignited, the flue damper is lowered, so as to retain the heat, smoke, and gases in the body of the furnace. In about two hours, when every sheet of the iron thus treated has become red hot, the whole is removed and placed under the hammer, for the purpose of working the oxide or scale, which has been formed on the surface of the sheets, into the body of each sheet; after which the pack is taken to pieces and re-packed, in precisely the same manner as before, taking care this time to interchange the sheets, placing those formerly in the centre of the pack on the outside, and *vice versâ*, and afterwards treating it again in the furnace as before. This packing, heating, and hammering process is repeated

some four or five times, which will, as a rule, be found sufficient to give the sheets the necessary polish, after which they are trimmed by the shears and passed one by one through the length of the annealing ovens, which will be sufficient to anneal and colour them properly for the market.

Utilising Tinplate Scrap.—In Germany and the United States, the process of M. Adolf Ott is in use for treating the scrap from tinplate works. The scrap is placed in large perforated copper drums, and kept rotating from 30 to 50 minutes in a tank containing warm hydrochloric acid. The tin and lead, if present along with about 5 per cent. of iron, undissolved in the acid, upon which the copper is lifted into a tank of water, then into one of alcali, and again into water, in all of which it is in turn rotated, in order to clean off all remaining acid from the iron scrap, which is then sent to the furnace. Any lead in the acid solution can be separated by adding some sulphuric acid, which precipitates it as sulphate of lead, after which the tin can be thrown down in the metallic state by immersing plates of zinc in the solution, and the precipitated tin powder, after washing with water, can be melted and cast into blocks. The final solution, which is an impure solution of the chlorides of zinc and iron, can be used either for impregnating such timber as railway sleepers, &c., or as a disinfectant.

The Different Processes for Steel-making.—In a recent paper by Mr. Thomas M. Drown, of Philadelphia, the different methods employed up to date for producing steel are classified under the following heads:—

(1.) From the ore direct by reduction and carbonisation. Ore steel.

(2.) From pig iron by decarburization. Pig iron steel. (*a*) By means of gaseous oxidising agents, as air in the Bessemer process; (*b*) By means of solid oxidising agents, as ore, saltpetre, &c., as in the puddling process, Heaton's process, &c.

(3.) From wrought iron by carburation. Wrought iron steel. (*a*) By fusion with pig iron, as in the Siemens-Martin process; (*b*) By fusion with carbonaceous matter, as in Mushet's, or the Indian processes; (*c*) By heating in charcoal below fusion, as in the cementation process; (*d*) By heating in an atmosphere of carburetted hydrogen without fusion, as in Macintosh's process.

Bessemer Process.—We are glad to note that the important

paper on the generation of heat in the Bessemer process, by Mr. Richard Akerman, of the Iron Office of Sweden, referred to in our last quarterly report, "Om vaermealstringen under Bessemer processen," which appeared in the Transactions of the Civil Engineers in Sweden, has been translated into English by Mr. C. P. Sandberg, and will be found in the Nos. of *Engineering* for July 5th, 19th, 26th, and August 16th.

In the Gienanth's Works at Kaiserlautern, in Bavaria, the Bessemer converters hold from 3 to 3¼ tons, which is melted in two cupolas. The pressure of the blast is from 1½ to 2 atmospheres, and the duration of the "blow" from 10 to 14 minutes. The steel produced is classified in seven numbers according to its degree of hardness.

At the Kœnigin-Marien Works, at Zwickau, the charge, which is about five tons, is melted in one of Krigar's cupolas, previously described in this report, using a fan-blast, and occupying about two hours' duration, after which the molten metal, in an extremely hot condition, is run into the converter, which has in its bottom seven tuyeres, each having seven cylindrical holes of one centimetre (0·393 inch English) diameter, the blast is then turned on and increased in strength until it has a pressure equivalent to one metre (39·37 English inches) column of mercury, and continued for twelve minutes, according to the Swedish system of producing steel direct. The end of the "blow" is determined mainly by observation with the spectroscope; the flame which at first is strongly luminous, becomes towards the end still more so and, like the sun, can hardly be resisted by the eyesight, whilst at the height of the boiling period it shows a thick brown vapour of manganese. During the whole period the spectroscope shows the brilliant yellow sodium line, after a little the lithium and potassium lines become visible in the red and violet divisions of the spectrum; about two minutes after the commencement of the "blow," certain yellow manganese lines are seen on the boundary between the yellow and green, a little after a second similar group of lines in the green itself, and, lastly, on the borders of the green and blue, a third group of lines all due to the same metal. At the same time that the second group of lines is seen in the yellow green, certain manganese lines become visible in the violet and along with the third group, other ones in the blue. These several appearances disappear in the reverse

order, and the disappearance of the first yellow group of lines signalises the end of the "blow." On tipping up the converter, which shuts off the blast, a cold bar of iron is dipped into it and withdrawn with its end coated with the slag, to which several small metallic globules adhere. On cooling in water this slag has a porous vitreous coating, and is liver-brown in colour on the surface, but internally greenish grey, and not unlike a blast furnace slag, whilst the adhering metallic globules, fully spherical and of a silver white colour, are very ductile and can be hammered out to five or six times their original diameter, without cracking on the edges. As the molten metal in the converter, owing to the extremely short duration of the "blow," has an exceedingly high temperature, some 300 to 420 lbs. of cold steel (crop-ends, &c.) is thrown into the converter, before pouring out into the moulds. The loss in this process is estimated at 9 per cent. of the cast iron employed; and the ingots are rendered more dense by being hammered under a fifteen ton steam hammer.

CONDENSING LIQUID STEEL.—At the Austrian Steel Works, at Neuberg, in Styria, Chevalier Stummer, of Trauenfels, has recently made an extensive series of experiments, with the object of welding together the interior particles of masses of cast steel so closely as to obviate the so-called honeycombed internal structure, so often observed in steel ingots. The effect of hammering large ingots of steel whilst their interior is still in a semifluid state, is well known, and has been practised at Essen by Krupp for the last twenty-five years. In 1856, an improvement on this system was patented by Bessemer, who employed a hydraulic press for the same purpose, and the experiments above alluded to have demonstrated satisfactorily, by exposing the semifluid metal to such great pressures, that it is possible to unite all these pores, which are filled with elastic gases into the centre of the ingot, where they occupy a very limited space, and in the case of the manufacture of cast steel ordnance, would be bored out, and consequently not affect the strength of the cannon. A pressure of from 6 to 9 tons on the square inch was found sufficient to compress the semi-liquid ingot, so as to produce an uniform structure throughout its mass, much better than could be done by even a 50-ton steam hammer, whose force is in great part absorbed by the exterior of the mass of steel.

FRANKLINITE SPIEGELEISEN.—In the United States no spiege-

leisen is at present manufactured, except the variety which is reduced from the Franklinite ores of New Jersey. As, however, the amount of carbon contained in this is even greater than in the best German spiegeleisen, it is found in practice to be quite equal, if not superior. The following analyses show the chemical composition of this spiegeleisen, and of the mineral Franklinite from which it is smelted:—

IRON BY HENRY.		FRANKLINITE BY DAHL.	
Metallic iron ...	81·363 ...	Sesquioxide of iron ...	66·11
„ manganese	11·500 ...	„ „ manganese ...	11·99
Carbon ...	6·900 ...	Oxide of zinc	21·77
Silicon ...	0·100 ...	Silica	0·13
Sulphur ...	0·137		
	100·000		100·00

Determination of Combined Carbon and Graphite in Iron.—According to Boussingault Annales de Chimie et Physique, 4th series, t. xx. p. 243, if the carbonaceous residue from the solution of cast iron is heated in the air at a temperature immediately below visible redness, the carbon previously in combination will be entirely burnt away, whilst the graphite is not affected; he, therefore, recommends that after such an incomplete combustion the residue be again heated to redness in a current of hydrogen gas and weighed, the difference of the weights of this and of the original residue will give the amount of combined carbon; on re-heating this residue in a current of oxygen, all the graphite will be burnt away, and the weight of residue after it has been reduced by again heating it in a current of hydrogen substracted from what it was previously found to be, indicates the amount of graphite present in the iron.

Estimation of Manganese.—Instead of the usual precipitants for manganese, Hugo Tamm recommends the carbonate of ammonia, which, according to him, when added in slight excess to a solution of the mixed chlorides of manganese and ammonium, precipitates the manganese in the state of ordinary protocarbonate of manganese so perfectly that no trace of the metal can be detected in the filtrate by sulphide of ammonium. The precipitated carbonate of manganese is allowed to settle down in a warm place (boiling is not

required), and afterwards filtered off; thus obtained it is a little denser than when thrown down by carbonate of soda, and can be washed with facility with hot water; if a double filter is employed, no trace of the precipitate will pass through. After drying, the precipitate is ignited, and is then estimated as Mn_3O_4. In determining the amount of manganese in native carbonate of iron or in spiegeleisen, 100 grains of the mineral or iron is dissolved in hydrochloric acid, adding chlorate of potash to completely oxidise the iron (the spiegeleisen can also be dissolved in nitrohydrochloric acid, but in this case the solution must be evaporated to dryness subsequently to remove all traces of nitric acid). In both instances, the iron is then separated from the manganese by succinate of ammonia as usual, and the manganese then precipitated from the filtrate by carbonate of ammonia; if, however, lime is also present, this must be separated from the manganese by the usual method before that metal can be determined. An examination of this method does not, however, warrant its being considered as an improvement upon the usual system of separating the iron from the manganese as a basic acetate, and then precipitating the manganese from the filtrate by bromine, which has the further advantage of not being in any way interfered with by the presence of lime in the solution.

CRYSTALLIZED PHOSPHIDE OF IRON.—M. Sidot, in the Compt. Rend. de l'Ak. des Sciences for May 27, 1872, describes a crystalline and highly magnetic phosphide, containing iron 87·9, and phosphorus 12·1, or agreeing with the formula, $Fe_8\ P_1$, which compound is formed when the vapour of phosphorus is passed over heated iron, and the product re-melted in a crucible.

August 26, 1872.

11, York Place, Portman Square, London, W.

PROCEEDINGS OF SCIENTIFIC AND TECHNICAL SOCIETIES.

Institution of Engineers and Shipbuilders in Scotland.—*Manufacture of Cast Steel.*—A paper was read on this subject before the above-named Institution, in April last, by Mr. B. D. Healey. The paper related mainly to the "open hearth" process of Siemens. This system is in extensive operation at the Landore Steel Works, Swansea, which are being laid out for an aggregate production of 1,500 tons of steel per week. Full details of the arrangement of the works and of all appliances connected with the furnaces in which the steel is produced, are given. It is stated that a pair of vessels, like those described, will produce about 400 tons of steel per week, when working charges of seven tons. The pig iron used in the process has to be carefully selected; the carbon in it should not be less than 3 per cent., silicon from 1 to 2 per cent., manganese not more than 3 per cent., and sulphur and phosphorus must not exceed ·05 per cent. In an appendix to his paper, the author gives several estimates as to the cost of producing ingots by the Bessemer and by the "open hearth" systems respectively. In comparing them, it will be necessary to make due allowance for the alteration that has taken place in prices since the paper was read:—

Approximate Cost of producing Ingots by the Bessemer Process in the South Wales District.

"From a pair of converters, I calculate 66 blows per week, which, in working charges of 77 tons each, gives a total of 462 tons Taking impurities and loss of metal at 13·5 per cent., the result. will be about 400 tons; which, again, would require about 20 tons of spiegeleisen, the cost being as follows:—

38 tons rail ends, at £5 10s. per ton	£209	0	0
212 tons hematite pig iron, at £5 10s. per ton ...	1,166	0	0
212 tons Scotch pig iron, at £4 per ton	848	0	0
20 tons spiegeleisen, at £9 per ton	180	0	0
60 tons coal for boilers, at 6s. per ton	18	0	0
70 tons coke for cupolas, at 15s. per ton	52	10	0
Repair of vessels, cupolas, ladles, moulds, and engines, at 5s. 6d. per ton	110	0	0
Labour to produce ingots, at 7s. per ton	140	0	0
Management and general expenses, including yearly overhaul	100	0	0
	£2,823	10	0

Being equal to about £7 1s. 2d. per ton of ingots produced, to which add 2s. 6d. for Royalty on the apparatus.

"In this estimate rail ends are taken at the price of pig iron, but they can be sold at a much better price.

Approximate Cost of producing Ingots by the "Open Hearth," process.

"From 4 furnaces working 15 charges per week—6 ton charges—I calculate a total yield of 360 tons; cost being as follows :—

340 tons hematite pig iron, at £5 per ton	£1,700	0	0
60 tons hematite ore, at £1 5s. per ton	75	0	0
15 tons spiegeleisen, at £9 per ton	135	0	0
270 tons coals, at 6s. per ton	81	0	0
45 tons coke, at 15s. per ton	33	15	0
Repairs of furnaces, cupolas, ladles, moulds, and cranes, at 6s. per ton	108	0	0
Labour to produce ingots, at 9s. 6d. per ton ...	171	0	0
Management and general expenses, including yearly overhaul	100	0	0
	£2,403	15	0

"Which is equal to about £6 13s. 8d. per ton of ingots produced; to which add 10s. for royalty on the apparatus. When the several patents have expired, the difference will be at least 7s. 6d. per ton in favour of the 'open hearth' process."

Rough Cost of Bessemer Plant for 400 tons per week.

Building 660 square yards	£660	0	0
2 cupolas for pig iron	600	0	0
2 Cupolas for spiegeleisen	300	0	0
2 Blowing engines	3,250	0	0
Condensing or compound, extra	300	0	0
2 Converters complete	2,450	0	0
Hydraulic pumps and accumulator	400	0	0
Hydraulic crane	250	0	0
2 ladle lifts	300	0	0
2 ingot tables	240	0	0
6 ladles and 2 carriages	200	0	0
2 blowers and engine	300	0	0
4 30 horse-power boilers and setting	1,600	0	0
Foundations for Blowing Engines	360	0	0
Sidings in the shop	90	0	0
	£11,300	0	0

Rough Estimate of Cost of "Open Hearth" Plant for 360 tons per week.

Building 980 square yards	£980	0	0
4 furnaces	2,200	0	0
Gas generators	1,360	0	0
Cupola and stage for same	300	0	0
Hydraulic pumps and accumulators	400	0	0
4 ingot tables	480	0	0
2 ingot cranes	500	0	0
4 ladle lifts	600	0	0
8 ladles and 4 carriages	300	0	0
2 blowers and engine	300	0	0
1 Boiler 20 horse-power and setting	300	0	0
Sidings in the shop	135	0	0
	£7,855	0	0

Institute of Mechanical Engineers.—*On the Strength of Rivetted Joints.*—The adjourned discussion on this paper took place in May.—Mr. J. G. Wright referred to some experiments that had been made by his firm to test the relative strength of the diagonal joint employed for steam boilers, in comparison with the

ordinary longitudinal joint. Two plates were tested with the diagonal joint at 45 degrees, and two with the longitudinal joint. They were of Staffordshire iron, of "Monmoor" best brand, 3 feet 6 inches long, 12 inches wide across the part tested, and $\frac{3}{8}$-inch thick. The joint was a single rivetted lap joint with punched holes, the rivets being $\frac{13}{16}$-inch diameter, and 2-inch pitch, and the width of the lap, $2\frac{1}{4}$ inches. The experiments were conducted by Mr. Kirkaldy, and the following table gives the results:—

Description of Joint.	Size of Plates.	Total Breaking Strain.	Resistance per sq. inch.		Proportionate Strength of Joint to Solid Plate.	
			Joint.	Solid Plate.		
	Inches.	Tons.	Tons.	Tons.	Per Cent.	
Diagonal at 45°	12·00 × 0·38	57·85	12·69	19·06	66·6	Mean
Do.	12·00 × 0·38	58·21	12·77	20·32	62·8	64·7
Longitudinal	11·90 × 0·38	41·45	9·17	19·90	46·1	Mean
Do.	12·00 × 0·38	44·54	9·77	19·37	50·4	48·2

Mr. J. Cochrane had made a number of experiments with a view of finding out whether, in regard to strength, there was really much advantage in drilling over punching. The results had shown that punching when well done left the iron practically as strong as drilling or otherwise forming the rivet holes, and was thus equally suitable for single rivetted lap joints; but where a number of plates had to be rivetted together one over another, the advantage of drilling over punching was then very great, as it ensured the exact correspondence of all the holes.

Mr. E. B. Martin said that from what he had seen of the diagonal-jointed boiler, that mode of construction seemed to recommend itself, not on account of the number of rivets in the diagonal joint giving it an advantage over the longitudinal joint, but simply because the longitudinal joint was the weakest in a boiler, and therefore if it were got rid of by one running midway between the longitudinal and transverse directions, a boiler so constructed must evidently be stronger.

THE INSTITUTION OF CIVIL ENGINEERS.—*On the Conditions which favour, and those which limit the Economy of Fuel in the Blast Furnace for smelting Iron*, by Mr. I. Lowthian Bell.—A

paper was read on this subject, in March last, before the above Institution, and an abstract of the same has already appeared in the JOURNAL. The discussion upon the paper occupied portions of two meetings.

Mr. Siemens said that Mr. Bell had watched blast furnaces more carefully than almost any other metallurgist. Some of the facts brought out in this paper were extremely interesting; amongst others the proof that the reduction of iron ore was a source of heat instead of, as was more generally supposed, the cause of loss of heat, and that reduction was effected at so low a temperature as 420 degs. Fahr. Mr. Bell had endeavoured to show that in the blast furnace the different operations constituting the process of smelting, might be carried on in such a way as virtually to complete one process before the other commenced; and from this the somewhat astounding conclusion was arrived at, that nearly all the advantages derived from the hot-air blast might be realised by simply increasing the size of the furnaces. The argument was not pushed to the practical conclusion, that the capacity of the furnace should be increased to the point of realising all the advantages of the hot blast, but the permissible temperature was limited to 960 degs. Fahr., at which point it was considered that the maximum effect could be had with a furnace of limited capacity. This argument was based upon the supposition that iron ore was reduced at 420 degs. Fahr., and that the second action, which was that of carbonic acid splitting up in contact with carbon, could only be accomplished at a higher temperature. If, therefore, the carbonic acid had all been split up in contact with carbon, and a zone had now been reached at which no more unburning of carbonic acid took place, the whole remaining capacity of the furnace would be reserved for the final action—that of the reduction of the ore to the metallic condition, and the production of a large proportion of carbonic acid gas in the gases leaving the furnace. He thought, however, that iron ores, as a rule, were not reducible at the extremely low temperature of 420 degs. Fahr., which was really below that of incandescence. In dealing with calcined Cleveland ore, he had no wish to doubt the fact; but if it was considered what this ore consisted of, it would be seen why its reduction and carbonization took place at that low temperature. In calcining Cleveland ore, 25 per cent. of volatilised matter was

evolved; therefore the calcined ore must be regarded as a sponge, consisting of extremely divided particles of iron ore. This sponge being brought into contact with the reducing gas, the carbonic oxide was mechanically absorbed in large quantities, and the reduction of the ore facilitated. The sponge into which Cleveland ore was converted by calcination might in effect be compared to platinum sponge, which, when a current of hydrogen gas was directed upon it, absorbed that gas so violently as to produce ignition. Again, when a solid bar of iron was exposed to a dry atmosphere, no appreciable oxidation would take place in one hundred or even in one thousand years. There were iron bars which, in old Roman buildings, had been exposed to the atmosphere for two thousand years and were not oxidized; but the same iron in a pulverulent condition would take fire instantly in a room, showing that the same material would behave differently under similar circumstances, according to its aggregate conditions. He had paid considerable attention to the reduction of iron ores, and he had found that, whereas hydrated ores or spathose ores were reducible at a low temperature, the peroxides required a higher temperature; whilst there were certain ores which were not reducible at a temperature below 1,500 degs. or 2,000 degs. Fahr. Those were the dense magnetic oxides which had no gases to give out, but were perfectly dense, like a piece of glass. Such compact ores, he believed, were not reduced in the upper part of the blast furnace in the way supposed—viz., by a current of carbonic acid, but only in a lower part of the furnace after they had become liquid. Certain ores, such as Ilmenite or Marbella ore, had been known to pass through the blast furnace, and to come out unchanged with the slag, notwithstanding the heat through which they had passed. He thought if such pieces of ore could tell a tale, they would speak of actions and reactions going on in the blast furnace which did not altogether tally with the beautiful stratifications Mr. Bell had shown. The author's conclusion, that the hot blast could not be beneficial beyond a certain point, was mainly based upon the argument, that with the temperature of the blast the heat towards the top of the furnace was also increased. But the temperature of the blast affected the temperature at the top of the furnace in the contrary way to what Mr. Bell had in his argument supposed. If the temperature of the blast were suddenly raised,

then indeed a rise would be perceptible throughout the furnaces, and the gases would escape at a somewhat higher temperature. In that case the same amount of oxygen would be introduced, and the same amount of carbon accompanied the charge; therefore there must be the same proportion of carbonic oxide and of carbonic acid issuing at the top, with an increase of temperature resulting from the greater importation of free heat with the blast. But if at the same moment when the temperature of the blast was raised, the relative quantity of coke in the furnace could be diminished to the point of producing not more than the requisite amount of heat, then a diminished quantity of products of combustion would have to impart its heat to the same quantity of ore; and inasmuch as the relative quantity of matter to be heated and smelted would be increased, it followed that the temperature of the escaping gases must be less than before, and that there must be advantage in raising the temperature of the blast. As to the effect of the increased temperature of the blast upon the temperature of the crucible of the blast furnace, he had explained his views very fully on a former occasion, when the author of the present paper argued on the other side of the question.* He might now state that, in advocating high temperature of blast, he did not look for any great increase of heat in the zone of fusion. He looked for the advantages of hot blast to the greater importation of heat into the whole economy of the blast furnace, resulting, he believed, necessarily, in great saving of fuel. In the statements of results which were frequently put forward, certain elements were generally wanting; and the most important of these was the relative quantity of blast used. If the temperature of the blast was increased without its being stated whether the same quantity was injected relatively to the amount of carbon in the charge, no positive conclusion could be arrived at; but these discussions would assume a more definite character, if the amount of blast was in all cases stated, and if the working of the furnace was only taken after it had been readjusted after a change of temperature to a minimum percentage of carbon with the charge. It could be easily conceived that with too much carbon the blast would produce an excess of carbonic oxide, and this would issue at the top of the furnace at a very moderate temperature. It might

* *Vide* The Iron and Steel Institute—Transactions, vol. i., p. 222.

be argued, in that case, that the hot blast produced unfavourable results; but if an increasing quantity of ore had been mixed with the coke, and the proportion gradually increased with increased temperature of blast till a positive minimum, to insure fusion of the mass, had been reached, the result would have been much more favourable. The general basis which he went upon was, that if free heat was imported into the furnace with the blast, that heat was produced economically in burning fuel into carbonic acid; whereas the blast furnace could at most produce carbonic oxide, with a proportion of, say, $\frac{1}{5}$th or $\frac{1}{4}$th of carbonic acid. The author had clearly shown that, in producing carbonic oxide, only about $\frac{1}{4}$th the amount of heat was produced from a given quantity of coal as when carbonic acid was formed. Therefore, every unit of heat applied to the blast outside the furnace represented really 3 units of heat produced by the combustion of coke within.

Mr. Samuelson thought the main question to be considered in the erection of a blast furnace plant was, that it should be economical from an engineering point of view. The assumption had been made by the author that in all the large blast furnace plants erected of late, there was waste of capital and corresponding waste of interest in the proportion of 100 to 66. He had endeavoured to check the calculations with certain presumed data, and found, by taking the quantity of pig iron made, and assuming the cost of the blast furnace plant to be in the ratio of the cubical contents of the blast furnace in which the iron was produced, the result would come out somewhat as Mr. Bell had stated. But here there were two fallacies. In the first place, it was assumed that a blast furnace plant with a capacity of 15,000 or 16,000 cubic feet would produce 350 tons of pig iron; while blast furnaces of 26,000 and 41,000 cubic feet capacity would only produce 450 and 550 tons. But he begged to point out that blast furnaces of 26,000 and 41,000 cubic feet capacity respectively would prouce 450 and 550 tons of iron of a better quality than No. 3; and the statement left it to be understood that the 350 tons produced by the smaller furnace would be of equally high quality. That was contrary to the experience generally of the Cleveland district, and it was that district upon which the reasoning was founded. He believed it was contrary to the experience of iron manufacturers in that district that a blast furnace of 15,000 or 16,000 cubic feet capacity should be able

to turn out 350 tons of foundry iron—that was to say, iron of equal quality to that of which 450 to 550 tons could be produced in the larger furnaces. He believed that in quality, or what was technically known as "numbers" alone, there would be a difference of at least one number, which meant, multiplied by the number of tons, not merely the interest upon the difference in the cost of the larger, as compared with the smaller plant, but the interest upon the entire plant. The improvement in "numbers," irrespective of any other economy, would be equal to the interest upon the entire plant put down to obtain the larger make. The second fallacy was, that the cost of blast-furnace plant had comparatively little relation to the cubical contents of the blast furnace which formed a part of it. As he had pointed out, on the occasion of the reading of his paper, the blast furnace itself only cost from one-fourth to one-fifth of the cost of the entire plant; and in nearly every other item, except the blast furnace itself, the cost was independent of the cubical capacity of the blast furnace. The dimensions of the blowing engines and boilers, of the heating stoves, and of the calcining kiln, were as nearly as possible not in the ratio of the cubical contents of the blast furnace, but in the ratio of the amount of air blown in, of coke consumed, and of iron produced, or, at any rate, in a ratio compounded of those items, between which there was comparatively little relative difference. And even in the cost of blast furnaces themselves of various dimensions, the cost did not increase in the ratio of the cubical contents or of the square of the diameter multiplied by the height, but in a much smaller ratio. The author would find in going through the calculation that, instead of the ratio of cost of blast furnaces, large and small being as 100 to 66, it would be nearly as 100 to 92, and he (Mr. S.) thought this slight additional capital would be more than covered by the saving of wages, and in other ways, quite apart from any saving of coke. But he would venture one step further, and, without entering into the intricate chemical questions which had been brought before the meeting, would assert that there was a saving in the amount of fuel consumed in the larger blast furnaces, and that therefore there were fallacies in the theory and in the facts brought forward on that subject.

Mr. J. T. Smith remarked that the result of the experience of the West Coast manufacturers, and of experiments recently carried

out for several weeks together, was that there was no economy of fuel in heating the blast beyond 1,100 degs. Fahr.; but at the same time, it was found that benefit was derived from increasing the temperature from 700 degs. to 1,100 degs. He explained the details of certain experiments that had been made at Barrow at higher temperatures than 100 degs., and the result of eight days' working was exactly the same per day as the working of the previous fourteen days, with the blast at a temperature of 1,100 degs.

Mr. G. J. Snelus had gone over the calculations in Mr. Bell's paper, and in many respects agreed with them, but there were certain conditions of the experiments about which there was no information. He did not think it was sufficiently considered that a good deal depended upon the shape of the furnace. He had found by tracing the phosphorus, when making Bessemer pig iron, that if he changed the burden of the furnace from ordinary iron to Bessemer pig it took fully a fortnight to clear out the old charge; while if he changed the burden from Bessemer pig iron to ordinary pig iron, he noticed the change in twenty-four hours. This proved that a good deal of material charged into the furnace found its way rapidly through the centre or some other part of the furnace, while another portion remained there a much longer time than was generally supposed. If the material found its way rapidly down the centre of the furnace, a great portion of the force or proper duty of the fuel must be destroyed; and if phosphorus found its way down rapidly it was almost certain that a good deal of iron ore found its way too, and this would react upon the carbon and silicon in the pig, and would change the "make" of the furnace from "grey" to "forge," or "white" pig. The furnace manager, then, to bring the iron back again to grey, put on an increased quantity of fuel, which was, of course, so much wasted, in the sense that it was only used to overcome a defect, not of height or capacity altogether, but probably of form of furnace, size of top, method of charging; or even size of pieces of ore. No doubt the amount of fuel used was frequently excessive, simply from an irregular method of charging the furnace; and as there were no data as to the way in which the furnace alluded to had been charged, it was difficult to judge of its efficiency in point of economy of fuel. He agreed that reduction of iron ores was more a matter of time than of temperature. He had made experiments upon most of the classes of ores used in

England, and he had found the ordinary Bilbao ore was reduced, in point of time, more rapidly than the denser ores of the Cumberland district, or even than the magnetic ores. The Bilbao ores could be perfectly reduced at a low temperature, and he had reduced the Marbella ore in a solid state in a cast iron tube, and, therefore, at a temperature far below 2,000 degs., so perfectly that he could cut the metal with a knife. Excessively high temperature probably facilitated reduction, but was not an absolute necessity for the reduction of any ore.

Mr. E. A. Cowper remarked that the author asserted that the same advantage could be got by increasing the size of a small furnace, as by increasing the temperature of the blast. No doubt practically the saving obtained by increasing the size of a small furnace could be effected by simply increasing the temperature of blast. To the majority of ironmasters this should be a very satisfactory fact, as by far the largest number of blast furnaces were of moderate dimensions, and some of them necessarily so, on account of the tender nature of some of the materials used, particularly the coke, which often would not bear a great superincumbent weight without breaking down to powder. Besides, some ores lay so close and compact, either when first put into the furnace, or after they had been subjected to the action of the furnace for a time, that it was impossible to get the blast freely through, if a furnace of great height was attempted. But if the majority of blast furnace owners could make moderate-sized furnaces work as well as the very large new ones, it would be a great advantage to them, and it was a fact that the higher temperature of the blast produced this effect. So far there was very little difference between Mr. Bell's opinion and his own. He would, however, give a statement of actual facts of the working of the same furnace with different temperatures of the blast, there being no alteration whatever in the blast furnace itself further than the necessary adjustment of the size of the tuyeres. The results obtained with this furnace working for several years with the ironstone, coke, and limestone of the same quality, the same amount of blast, and under the same management, showed that about 24 cwts. of coke was the consumption, when the blast was at a temperature of 1,000 degs., Fahr. By increasing the temperature of the blast to 1,420 degs., a saving of 4 cwts. of coke per ton of iron had been effected.

Mr. David Forbes remarked that the object of the paper was to maintain the opinion that the working of blast furnaces had already arrived at perfection, at least as regarded the dimensions of the furnace and the heat of the blast applied in working them. He did not agree in that opinion, but admitted that the larger furnaces had not as yet produced effects equal in proportion to the increase in the size. He, however, maintained, as far as experience had gone, that there had been appreciable benefits from what had already been done in this direction, and that there had been greater economy in the use of the larger furnaces than in the use of the smaller ones which previously obtained. With regard to Mr. Bell's calculations, he said the greatest care should be taken that the data on which these were founded should be established facts. With respect to the temperature of fusion of iron, he remarked that authorities put this at points ranging from 1,050 degs. to 1,812 degs. centigrade. With such differences it was impossible to take either of these figures as the basis of the calculation without obtaining results totally at variance with one another. Then, again, he maintained that it was not the point of fusion of the slag, but the heat at which the slag actually formed in the furnace which had to be considered. The temperature at which slag was firmer, and the temperature at which the molten slag once formed could remain liquid, were totally different, as had been shown by Professor Plattner; consequently, in the blast furnace there must be taken into consideration the greater heat required for forming the slag before it came to the molten state—not the mere melting point of the slag itself. As to the shape of the furnace, the author seemed to think the great utility of the higher furnaces and larger capacity existed solely in the capability of the upper part of the furnace to absorb the extra heat formed below in the focus of fusion. In this opinion he disagreed. A modern iron blast furnace was a large instrument, and rather an expensive one to work with; but smaller, yet analagous, experiments could be made. He, therefore, took a couple of copper blast furnaces both of the same size—*i.e.*, of the same cubical capacity—each furnace being 15 feet high, but built in totally different forms. The conditions otherwise were the same in both. In the larger iron furnaces, which had been increased from 6,000 to 30,000 cubic feet in capacity, the belly of the furnace had been mainly enlarged, and the focus of fusion had not been

increased in the same proportion. He had smelted as much as 10,000 tons, so that the experiments were not on a small scale, and the results he thought could be relied upon. In those experiments he diminished very largely the upper part of the shaft, and increased the focus; consequently, whilst the smelting power of the furnaces was greatly increased, the gases went out so cool at the top that they were hardly capable of burning paper, whereas but a few feet below the heat was very great. This was a proof that the alteration of form might be of the utmost importance. The mistake had been, not in the larger capacity of the furnaces, but that they had been made very capacious above and not sufficiently capacious below, where the whole of the smelting work was going on. As a step in this direction, he might instance the case of the Raschette furnaces in Russia. He did not consider them perfection, but still those furnaces were doing more work than, according to their capacity, they could have been expected to do; and he had no doubt, by a modification of form in the larger furnaces, still higher results would be obtained. It was not a question of mere capacity, but of how the internal dimensions of the furnace were arranged. He was still of opinion that the blast had not yet been employed too hot. But increased temperature of blast meant increased engine power and larger tuyeres, or the quantity of oxygen sent into the furnace would be diminished, since the higher the temperature, the greater became the volume of the air. In practice, however, the quantity of oxygen in the air was often actually reduced, and more work was expected to be done merely by the increased temperature of the blast. This, he believed, was one reason why the results hitherto had not been more satisfactory and conclusive.

Mr. T. Whitwell said there was a remark in the Paper with regard to the "proper size" of furnace. The Author took it for granted that a "proper sized furnace" must be one of 12,000 to 15,000 cubic feet capacity, no matter what was the material to be smelted; whereas it appeared to him that every furnace must be built to suit the material to be operated upon. It was evident that in every furnace there must be proportions of height and diameter at which minerals were reduced in the most economical manner, a proper quantity of blast being injected into the furnace. If those proportions were exceeded, true economy could not be looked for. The furnace, therefore, that did its work best on any

given material was the proper size of furnace for that material, whether of 15,000 cubic feet capacity or less. One furnace at Consett had been examined two years ago by Mr. Bell, who stated that it contained 9,114 cubic feet; and when 6,000 cubic feet of blast per minute were thrown into it at 1,350 degs., the product was 380 tons per week of grey iron, from material containing 46 per cent. of metallic iron, with a consumption of coke of 18 cwt. per ton of iron. But when into the same furnace 8,000 cubic feet of blast per minute, instead of 6,000, were forced at a temperature of 1,150 degs., the product was 480 tons per week in the place of 380. with a consumption of $19\frac{1}{4}$ cwt. of coke per ton, instead of 18 cwt. The results, with a consumption of 18 cwt. of coke, extended over a year and a quarter; but since the furnace had been driven up in its make 25 per cent., the temperature of the blast being lowered, it had not worked so economically as during the previous period, He might say with regard to temperature of blast, so satisfied were the Consett Company of the benefit of having constantly a high temperature of blast, that they always kept as nearly as they could to 1,400 degs.; and the furnaces were each producing an average of 457 to 460 tons of iron per week. The furnaces were 55 feet high; some with 20 feet, others with 21 feet, and one with 22 feet 6 inches diameter of bosh. The author had contended that in Cleveland, with furnaces of proper dimensions, viz., with a capacity of 15,000 or 16,000 cubic feet, it was unnecessary to raise the temperature above 900 degs., and that then the best results were obtained, any higher temperature being accompanied by waste. But so far as his knowledge as a practical iron-smelter went—and he had visited the works of most of the ironmakers in Cleveland—the Cleveland ironmasters were working as nearly as possible at a temperature of 1,150 degs.; and the highest temperature of blast, so far from being a source of waste, was known to be absolutely indispensable in producing regularity of quality, and correcting the many maladies to which the blast furnace was liable, resulting from bad coke, badly-calcined stone, wet, accidents, and other causes. The engineer of one of the companies most recently started had said, the furnaces were being worked with blast at a temperature of 1,190 degs., as indicated by Siemens' copper ball pyrometer, which he regarded as superior to all others, inasmuch as the longer it was used the lower temperature it showed. Other

instruments got to show a higher temperature; but Siemens' pyrometer consisted of a copper ball of a certain size which, when heated, was plunged into an imperial pint of water; the ball became reduced in bulk by frequent use in very hot blast, so that the relative proportions of the water and the copper became changed, and the indications were always rather within the estimate than otherwise. Increase of height in a furnace without increase of temperature would not give true economy. In proof of this he might state that about a year and a half ago, some furnaces in Cleveland were rebuilt, and raised from 55 feet to 80 feet in height, having boshes of 26 feet, and a capacity of 26,000 cubic feet. Those furnaces were worked at 850 degs., or 50 degs. below the point stated by Mr. Bell to be most economical, and consumed 24 to 25 cwt. of coke per ton of iron, or $2\frac{1}{2}$ cwt. more than the alleged proper quantity of coke per ton of pig. The Thornaby furnaces, 60 feet high and a 20-feet bosh, with blast at 1,100 degs., worked over the same period on similar material with 23 to 24 cwt. of coke per ton of iron, though the dimensions of the furnaces were 12,000 feet as compared with 26,000 feet in the other case. From what had been said by Mr. Smith, of Barrow, it might be supposed that there was a difficulty in working at high temperatures on account of the valves giving way; but, as far as Consett was concerned, four furnaces were in full blast with eighty of his water valves and seats. Of these, forty had been at work for nearly a year and a half, with blast from his firebrick stoves at a temperature of from 1,200 degs. to 1,450 degs., without any failure of the apparatus.

Mr. Isaac Lowthian Bell, in reply upon the discussion, observed that Mr Samuelson supposed the fact had been lost sight of, that the larger furnaces might make better iron than those of inferior dimensions. That was a mistake. The object had been to compare consumption of fuel; but it would have been a fallacy to say, two furnaces using the same quantity of fuel per ton of iron were working with equal economy, if one was making No. 1 and the other white iron. Hence, when it was said that a furnace of 16,000 cubic feet capacity performed its duty as efficiently as one of 26,000 cubic feet, the quality of the product was not lost sight of; and in stating that such were the working results he spoke from some years' experience. Again, Mr. Samuelson pointed out that, in the actual increase of cost in a plant embracing furnaces

of the largest size, it was the furnace alone which was more expensive, the blowing engines, heating stoves, &c., remaining the same as before, and that the interest on capital was not in the proportion of 100 to 66, as he maintained, but as 100 to 92. To this he would reply that his remarks about interest applied solely to the furnace itself. He had ample experience of the importance of proper attention being given to both the shape of the furnace and the mode of charging; but his observations had reference to the most perfect action of the furnace, and perfect action implied perfect treatment. It appeared to be thought by Mr. Siemens that his argument was partly founded upon the action of the blast furnace being susceptible of division in accordance with the diagrams he had exhibited; and that it was necessary to suppose each operation in the smelting process was performed in one division or zone, and in no other. Now, this view was contrary to his expressed meaning. He maintained that it was a convenient mode of describing the operation; and he had not the slightest doubt the more those distinctive zones of action were kept separate the better, and more economical were the results; but it was not less true that slight alterations in materials, in the atmosphere, and in charging, might and did considerably modify the work carried on in those different zones, which led to a deviation from what he on another occasion spoke of as the perfection of blast furnace working. He had never stated that the hot blast was not a *bonâ fide* improvement. On the contrary, he stated and believed that in Neilson's time it was one of the most important improvements which ever had been introduced into the manufacture of iron. Nevertheless he found that, by raising the height of a furnace from 53 to 71 feet, the consumption of coke per ton of iron was reduced from 40 cwt. to about 28 cwt., which corresponded exactly with that obtained by heating the air to about 800 degs. or 900 degs. Fahr. Again, in the opinion of Mr Siemens, the value of his views were dependent on an ore of iron being reduced at 420 degs. Fahr.; but he alleged that reduction commenced at a temperature of 420 degs., and was not complete until the ore reached a point in the furnace where the temperature was about 1,000 degs. Fahr. In his experiments many kinds of ores were operated upon, and it was somewhat remarkable that of all ores tried, that of Cleveland was about the least susceptible to the reducing action of carbonic oxide. It was

true the denser ores, such as the magnetic oxides, in their natural state, were slow in yielding oxygen to carbonic oxide. He had made a trial of Marbella iron ore. In its raw state it lost, at a temperature of melting zinc (782 degs. Fahr.), in nine hours, only about $\frac{1}{4}$th of the oxygen removed from calcined Cleveland ironstone; but when the Marbella ore was previously heated red-hot, its loss in this respect was equal to that of Cleveland, and its power of splitting up carbonic oxide was remarkably intensified. Thus, while in its raw state only about 3 parts of carbon per 100 of iron were thrown down against 6·7 parts in the Cleveland, when the ore of Marbella was roasted, 167 per 100 of iron were found in the ore which had been operated on. The specimens were acted on simultaneously, by exposure to the current of carbonic oxide in a vessel kept hot by a bath of melted lead, and the temperature ascertained by slips of metal. In this case, zinc melted and antimony was not changed; the heat therefore was between 782 degs. and 842 degs. Fahr. He had been found fault with, as well as Mr. J. T. Smith, of Barrow, for not giving the quantity of blast received by the furnace in different experiments. The question of this quantity was spoken of as if it were easy to measure the air going into a furnace, while in reality it was very difficult. The fact was, that no engine drove out of the blowing cylinder all the air it compressed, and the loss in the hot air apparatus prevented the quantity being ascertained by displacement. It was equally difficult to calculate the volume by the area of the blast pipes, which were always being altered, by changes in the obstruction offered by the materials in the furnace itself. Let it not, however, be supposed, in the estimates he had given, that the quantity of air had been overlooked; indeed, without knowing how much air was consumed, no calculation could be made how much heat was conveyed by the blast into the furnace. In his opinion, the only way to obtain this indispensable knowledge was by the aid of the chemist, and he must be careful in coming to a conclusion. The mode adopted was analyses based on the escaping gases; but as these varied much in composition, a sufficient number of experiments must be made to get an average result. This being done, and the quantity of carbon used per ton of iron entering the furnace being known, and analysis affording the relation it bore to the nitrogen in the gases, the weight of air used was then found. To

show how near to the truth these calculations were, he would quote one of the best among his numerous analyses:—

				Cwt.
Carbon per ton of iron in coke and limestone				17·35
Less taken up in iron				·60
Weight of carbon in gases				16·75

Average composition of gases:

			Carbon.	Oxygen.
Nitrogen	54·10			
Carbonic acid	17·43	=	4·75	12·68
Carbonic oxide	28·00	=	12·00	16·00
Water (from coke) ...	·45			
Hydrogen (from blast) ...	·07			
Cwt.	100·05		16·75	28·68

Hence the blast per ton of iron was—

Nitrogen, as above	54·10
Oxygen therewith	16·16
Moisture	·81
Cwt.	71·07

The proof of its correctness was ascertained as follows:—

Oxygen per ton of iron, as above	Cwt.	28·68
Brought in by blast, as above	16·16	
Moisture in blast would give	·72	
Iron ore from oxide of iron, phosphoric acid, &c. ...	9·00	
Limestone	2·59	
		28·47
Difference for experimental error, &c.		·21

Air highly superheated was the direction in which economy was chiefly to be sought for, according to Mr. Siemens. He, on the contrary, considered that an equilibrium in the opposing actions at work in a blast furnace set a limit to this, because, after the gases exceeded a certain temperature, a secondary action was set up, by which carbonic acid was returned to the state of carbonic oxide, and this neutralised the effect of the extra heat added to the air. Mr. Siemens practically said it was not so, but he did not support this experimental proof. Mr. Siemens seemed to infer that he had first propounded a theory and then sought for his facts. He admitted at an early period having stated his disbelief in the power

to apply beneficially the blast heated to the extent anticipated by others, for two reasons, first, by decreasing the fuel the air decreased, so that when the diminished quantity of blast had to carry an increased quantity of heat, its temperature rose more rapidly than some had supposed. Thus, if a ton of iron could be made with about 21 cwt. of coke, at a temperature of 811 degs. Fahr., the reduction of the coke to 15 cwt. required a rise of temperature, *cæteris paribus*, to 2,289 degs. Fahr., which was probably unmanageable. The change in the composition of the gases exerted, as he had said, a cooling effect, the extent of which, at the period just referred to, had not been determined. This cooling effect was manifested in the diminution of carbonic acid, as might be seen by the following table, in which was exhibited the composition, in round numbers, of 1,000 units of the heat evolved in blast furnaces, the gases of which were carefully analysed :—

Temperature of blast	900°	1,100°	1,320°	1,360°
1. By production of carbonic oxide	480	500	490	510
2. By blast	130	150	160	190
3. By production of carbonic acid from carbonic oxide ...	390	350	350	300
Units	1,000	1,000	1,000	1,000

It would be seen that as the relation of blast heat increased, that from the conversion of carbonic oxide to carbonic acid decreased. Let the effect be now examined of reducing the weight of coke, so as to avoid the high temperature of the gases with superheated air, and the unburning of carbonic acid. Two tables were here given : in the the first a ton of iron was supposed to be produced with 21 cwt. of coke, with air at about 800 degs. Fahr. ; and in the second 18 cwt. of coke was the assumed consumption, and the deficiency of heat was made up by conferring additional heat on the blast. 21 cwt. of coke was equal to 20 cwt. pure carbon ; of this 6 cwt., or thereabouts, burnt to

Carbonic acid, would afford	48,000	cwt. heat units.
14 cwt. burnt to carbonic oxide	33,600	,, ,,
Blast would contain about	11,400	,, ,,
Total	93,000	,, ,,

The above weights of carbon converted into carbonic acid and carbonic oxide afforded these two gases volumetrically, as 43 of the

former to 100 of the latter; which, according to his experiments, under the circumstances, exhibited about the neutral position in regard to reduction of iron oxide. Reducing now the coke to 18 cwt. for each ton of iron, representing in round numbers 17 cwt. of pure carbon, then

6 cwt. of carbon burnt to carbonic acid gave, as before	...	48,000 units.
11 ,, ,, carbonic oxide	...	26,400 ,,
Leaving the blast to supply	...	18,600 ,,
Total, as before	...	93,000

In the latter case, however, the proportion of carbonic acid to carbonic oxide was as 55 volumes of the former to 100 of the latter, which constituted an extent of saturation with oxygen impossible to be maintained when smelting the Cleveland ironstone. It had been alleged that by raising the temperature of the blast from 1,000 degs. to 1,442 degs. Fahr., the consumption of coke had been reduced from 24 to 20 cwt. per ton; when using the same quality of coke, similar ore, the same pressure of blast, and he presumed he ought to have included the same quality of atmosphere. Now, it was most difficult to secure this perfect identity; but, irrespective of this, he maintained that in a perfect furnace the consumption of fuel with air at about 900 degs. Fahr. was a mere fraction above 21 cwt., and ought never to amount to 24 cwt. of best Durham coke. But if the improvement had been due solely to the heat in the blast, he fancied that a difference of nearer 1,000 degs. than 442 would have been needed. The results obtained at Consett, which results were, in the frankest possible manner, furnished to himself, had been quoted in the discussion. It was said anything could be proved by figures, and if ever there was a case in which this could be truly applied, it was in the working of blast furnaces. Now, it was clear in the long run, if a higher temperature in the blast possessed the virtue claimed for it, then there should be, as a rule, a saving of coke as the temperature of the blast was increased. He therefore took nearly a year's workings of a furnace using superheated air—always, it was stated, using similar minerals and similar fuel. The temperatures were placed in a column in the order of their intensity, beginning at the lowest. If Mr Whitwell was absolutely correct, then the coke consumed should be the lowest when the temperature of the air was highest, and *vice versa*. The following table showed that this was not so:—

Average Temperatures under 1,150° Fahr.—Fifteen weeks.

Temp. Fahr. °	Coke per Ton Iron. cwt.	qrs.	lbs.	Iron made. Tons.
1061	22	0	14	460
1098	18	0	21	484
1106	22	3	12	455
1112	18	2	26	465
1122	17	2	26	477
1126	19	0	3	513
1132	19	1	20	532
1133	20	2	15	437
1133	19	2	26	452
1134	17	0	18	467
1140	20	1	6	447
1144	19	0	19	435
1145	19	2	9	488
1148	19	2	13	491
1149	19	1	18	483

Average.

Temp. Fahr. °	Coke per Ton. cwt.	qrs.	lbs.	Iron. Tons.	Yield Ore. Per cent.
1125	19	2	8	472	45·63

Temperatures between 1,150° and 1,200° Fahr.—Sixteen weeks.

Temp. Fahr. °	Coke per Ton Iron. cwt.	qrs.	lbs.	Iron made. Tons.
1152	18	3	4	537
1158	19	1	25	476
1170	19	1	19	543
1172	18	3	20	539
1173	19	0	1	483
1174	19	3	23	455
1176	19	2	10	507
1177	19	3	22	415
1178	19	0	19	476
1181	19	1	27	462
1183	22	3	7	201
1183	19	3	24	491
1184	20	2	1	455
1184	19	1	1	456
1194	19	1	26	495
1199	19	1	9	503

Average.

Temp. Fahr. °	Coke per Ton. cwt.	qrs.	lbs.	Iron. Tons.	Yield Ore. Per cent.
1177	19	2	4	468	46·27

Temperatures between 1,200° and 1,250° Fahr.—Twelve weeks.

Temp. Fahr. °	Coke per Ton Iron. cwt.	qrs.	lbs.	Iron made. Tons.
1201	18	1	24	506
1201	19	0	13	577
1208	20	2	23	465
1208	19	0	21	470
1208	18	3	14	462
1219	19	0	22	510
1230	19	0	26	511
1236	18	3	3	470
1236	20	2	1	478
1236	19	0	19	478
1243	19	3	19	482
1245	20	1	19	468

Average.

Temp. Fahr. °	Coke per Ton. cwt.	qrs.	lbs.	Iron. Tons.	Yield Ore. Per cent.
1221	19	2	4	491	46·41

Temperatures 1,250° Fahr. and above.—Four weeks.

Temp. Fahr. °	Coke per Ton Iron. cwt.	qrs.	lbs.	Iron made. Tons.
1260	19	1	18	484
1283	20	0	20	508
1292	17	2	8	431
1316	19	2	4	504

Average.

Temp. Fahr. °	Coke per Ton. cwt.	qrs.	lbs.	Iron. Tons.	Yield Ore. Per Cent.
1288	19	0	19	457	45·49

He did not deny that the application of superheated air had been most beneficial at Consett, but it was applied to furnaces of an imperfect character; he meant as regarded size, and, therefore, power of saturating the gases with oxygen. It was alleged, and probably rightly so, that the materials were unmanageable in a very high furnace, say 80 feet, and, consequently, Mr. Whitwell had to be content with a furnace 55 feet high; and here, as with Neilson, who greatly improved the action of a small furnace by using air at 600 degs. Fahr., Mr. Whitwell added to the power of a furnace of moderate dimensions at Consett by using air at 1,100 degs. or 1,200 degs. Fahr., instead of 800 degs., with which it was compared. Mr. Smith said he found an improvement by raising the temperature of the air from 700 degs. to 1,100 degs. Fahr., but more when he raised it to 1,500 degs., and this, it was alleged, was a proof that this doctrine was erroneous. But Mr. Smith was working with a less capacious, and, therefore, a less perfect furnace than those used in Cleveland, and was compelled to do so from the nature of the Lancashire ore. Mr. Whitwell then proceeded to state that a furnace 85 feet high, with a bosh of 26 feet, in Cleveland, had been consuming 24½ cwt. of coke per ton of iron. Mr. Bell could not be answerable for the improper working of any particular furnace, for 24½ cwt. was far too large a quantity of fuel with air heated to 900 degs. Fahr. Against this, he would quote two works using similar material in furnaces 80 feet high and upwards. At one, the air was heated to 1,100 degs. or 1,250 degs. Fahr., at the other at from 800 degs. to 900 degs. Fahr. The consumption of coke at the two corresponded with $\frac{1}{10}$ of a cwt. per ton of produce. Mr. Whitwell spoke of the temperature in the works at Middlesbrough being usually 1,100 degs.; if so, what Mr. Bell called 900 degs. others called 1,100 degs. He often heard of these high temperatures, and yet they rarely were capable of fusing antimony, which melted at 842 degs. Fahr. Mr. Forbes objected to the supposition that in the blast furnace perfection had been nearly approached in the coke consumed, for such a supposition was tantamount to retrogression. But Mr. Forbes could not pretend that a chemist who warned the chemical manufacturer that it was in vain for him to enlarge his plant or expend money in the hope of getting more than 49 lbs. of oil of vitriol from 16 lbs. of sulphur, was performing a useless duty; and what

had been done for the maker of vitriol he had attempted to accomplish for the ironmaker. He did not attempt in so complicated a question to draw a hard line, but the opinions to which he had given expression were the result of lengthened examination and experiment, confirmed by considerable experience at the furnace itself. Mr. Forbes dwelt on the probability that he was incorrect in some of the figures constituting the duty of the blast furnace. He believed this was not very material for the general argument, for although in some cases there existed much difficulty in determining the exact quantity of heat absorbed, he thought there was presumptive evidence of their general correctness. He had examined the heat development based upon the state of oxidation and quantity of carbon burnt, varying from 15 to 30 cwt. per ton of iron, smelting ores yielding from 40 to 60 per cent. of metal. The limestone consumed was sometimes 18 cwt. per ton of iron, and sometimes it was entirely absent. Thus, the factors varied considerably, and yet the final results corresponded very closely, showing, he submitted, a fair approach to general truth. With regard to the shape of the furnace alluded to by Mr. Forbes, the case of copper ore afforded no light on the question under discussion. In an iron furnace it was not mere fusion which had to be dealt with, but a complicated series of chemical reactions which were not analogous to those in copper smelting. He was quite aware of the importance of shape in a blast furnace; but he maintained that when the gases were as fully oxidized and cooled as the process would admit of, no change of shape could effect further good. His opponents should now apply their minds to proving that the relation of carbonic acid could be made to exceed the proportions mentioned by him, instead of dealing in general statements about the size of the furnace, its shape, or the temperature of the blast. It must not be supposed that he pretended that some modification of the process of smelting an ore of iron might not be attended with economy in the quantity of fuel consumed; it must be distinctly remembered the discussion was on the process as it was now carried on, and whether there were limits in size of furnace, or in temperature of blast under present conditions of the process, which it was useless to exceed. Before concluding, he would observe, in reference to the heat of the blast, that his remarks had exclusive reference to the possi-

bility of employing a furnace of such dimensions as to render it unnecessary to raise this beyond that which was usually obtained in the ordinary stoves, say 800 or 900 degs. Fahr. There were many cases in which superheated blast had been highly advantageous, as, example, when circumstances prevented the use of very large furnaces, as at Consett and elsewhere. Taking, however, the fire-brick stove, as proposed by Mr. Cowper, or modified by Mr. Whitwell, it was an admirable form of apparatus, inasmuch as by its use the least possible amount of friction was opposed to the passage of the last, loss of air was practically avoided, and, in addition, it possessed manifest advantages in point of durability.

NOTES ON
THE BRITISH IRON AND STEEL TRADES.

New Companies.—Since the publication of the last number of the Journal of the Institute, the following new companies connected with the iron and steel trades have been introduced :—

	Capital.
Bede Metal and Chemical	£250,000
Mitchell's Worsborough Dale Foundry	30,000
Middlesbrough Wrought Nail	30,000
Taylor, Lang, & Co., Castle Iron Works, Staleybridge	50,000
Forest of Dean Iron Ore	250,000
North of Ireland Iron Ore	200,000
Erimus Iron	50,000
Thames Iron Works and Shipbuilding	300,000
Ibbotson Brothers & Co., Globe Iron Works, Sheffield	120,000
Knightor, Treverbyn, and Resugga Hematite Iron Ore	105,000
Lincolnshire Iron Smelting	75,000
Staffordshire Galvanising and Corrugated Iron ...	10,000
St. Austell Hematite Iron Ore	60,000
Hungarian Chrome, Coal, and Iron	200,000
Lamplugh Hematite Iron Mining	50,000
Monkland Iron and Steel	400,000
Torbay Hematite Iron	200,000
Skerne Iron Works	200,000
Omoa and Cleland Iron and Coal...	200,000
Northern Titanic Iron Ore and Smelting	100,000
Loftus Iron	100,000
Somorostro Iron Ore	200,000
Mold Foundry	10,000
Finland Charcoal Iron Works	100,000
Industrial Coal and Iron	150,000
Redbourn Hill Iron and Coal, Frodingham... ...	60,000
South Staffordshire Iron Works	70,000
Pensylfoly Iron Mining...	4,000
Turnbridge Iron Works	60,000
Phœnix Bessemer Steel, Sheffield	100,000
Davy Brothers, Limited, Sheffield	100,000
Johannishagen Mining	8,000
Eva Iron Ore (Spain)	250,000
Henry and Samuel Barker & Co., Mexboro', Yorkshire	30,000
Winford Red Hematite Iron Ore...	25,000
Beatwood Coal and Iron	240,000
Hodyoad Iron Mining, Cumberland	9,000

Quebec Iron	£90,000
Carmarthenshire Anthracite Coal and Iron ...	60,000
Colwyn Hematite Iron Ore	50,000
Britannia Iron Works, Middlesbrough	200,000
Cantabrian Iron (Spain)	60,000
Wear Rolling Mills, Sunderland	350,000
Merry & Cuninghame	1,000,000
Charlton Iron Works (Sheffield)	125,000
Eldorado Iron Syndicate	100,000
J. C. Hill & Co., Oakfields Iron Works, Newport, Mon.	110,000

PRODUCTION OF PIG IRON IN CLEVELAND.—The Ironmasters' Association in Cleveland have published the following as the make of iron in that district during the three months ending July 31st last:—

	1872. Tons.		1871. Tons.
May	168,795	...	164,082
June	162,207	...	155,912
July	162,603	...	158,126
	493,605		478,120

At the end of July, 1872, 132 furnaces were blowing, as compared with 119 at the end of July, 1871.

BOARD OF TRADE RETURNS.—The Tonnage of the Exports of IRON and STEEL from the United Kingdom during the first seven months of the present year, compared with that for the same periods of 1870 and 1871, has, according to Board of Trade returns, been as under:—

IRON.

	Countries to which Exported.	1870. Tons.	1871. Tons.	1872. Tons.
PIG	To Germany	70,007	107,420	168,753
	,, Holland	91,283	130,007	198,049
	,, France	83,286	31,317	61,758
	,, United States	62,864	104,373	141,823
	,, Other Countries ...	158,828	196,486	240,085
	Total	466,268	569,603	810,468
BAR, ANGLE, BOLT, AND ROD	To Germany	7,612	8,809	8,609
	,, Holland	6,616	4,458	4,450
	,, France	4,136	285	593
	,, Italy	20,845	19,342	12,831
	,, Turkey	7,858	5,652	5,410
	,, United States	26,188	37,773	44,284
	,, British North America.	21,576	24,464	28,908
	,, ,, India	20,855	15,681	10,649
	,, Australia	8,051	6,220	11,968
	,, Other Countries ...	66,675	71,105	63,112
	Total	190,412	193,789	190,814

RAILROAD OF ALL SORTS ...	To Russia ...	140,548	54,539	27,473
	,, Sweden ...	1,118	5,345	7,811
	,, Germany	41,620	36,992	23,530
	,, Holland	13,380	6,580	2,462
	,, France ...	197	1,646	255
	,, Spain and Canaries	9,457	6,358	6,339
	,, Austrian Territories	24,029	8,634	6,733
	,, Egypt	1,564	1,531	10,173
	,, United States ...	238,540	287,169	300,316
	,, Spanish West India Islands	2,342	1,278	1,006
	,, Brazil	2,600	12,271	12,840
	,, Peru	8,978	14,667	22,204
	,, Chili	10,084	7,223	2,075
	,, British North America.	22,412	37,138	45,572
	,, ,, India ...	113,564	27,655	8,220
	,, Australia	5,296	10,752	12,584
	,, Other Countries	33,872	44,694	43,012
	Total ...	669,601	564,472	532,605
WIRE OF IRON OR STEEL (except Telegraph Wire) galvanised or not		13,873	13,548	19,321
HOOPS, SHEETS, AND BOILER & ARMOUR PLATES ...	To Russia ...	4,706	9,432	5,749
	,, Germany	6,570	6,946	6,928
	,, Holland	4,312	4,670	4,799
	,, France ...	2,944	522	1,864
	,, Spain and Canaries	2,820	3,398	3,148
	,, United States ...	22,839	23,969	19,315
	,, British North America.	6,539	8,947	8,930
	,, ,, India ...	10,489	7,425	11,327
	,, Australia	8,045	7,936	10,833
	,, Other Countries	34,486	34,508	41,572
	Total ...	103,750	107,753	114,465
		Cwts.	Cwts.	Cwts.
TIN PLATES	To France ...	24,534	15,880	36,965
	,, United States ...	973,511	1,037,244	1,082,117
	,, British North America.	36,041	43,605	44,645
	,, Australia	29,116	62,049	55,000
	,, Other Countries	200,939	242,793	206,730
	Total ...	1,264,141	1,401,571	1,425,457
		Tons.	Tons.	Tons.
CAST OR WROUGHT AND ALL OTHER MANUFACTURES (EXCEPT ORDNANCE UNENUMERATED) ...	To Russia ...	10,352	9,632	8,633
	,, Germany	12,176	12,876	14,650
	,, Holland	3,065	5,299	8,165
	,, France ...	2,956	2,098	2,722
	,, Spain and Canaries	4,288	2,509	4,149
	,, United States ...	4,459	5,375	8,013
	,, British North America.	7,252	9,342	12,964
	,, ,, Possessions in South Africa	1,124	1,372	1,989
	,, ,, India ...	18,985	19,424	12,681
	,, Australia	11,423	8,630	11,432
	,, Other Countries	62,141	57,528	65,989
	Total ...	137,221	134,085	151,387
IRON, Old, for re-manufacture		67,927	72,518	68,958

STEEL.

UNWROUGHT...	To France ...	1,934	502	1,846
	,, United States ...	8,903	16,765	14,132
	,, Other Countries	8,940	8,287	9,665
	Total ...	19,777	19,554	25,646
MANUFACTURES OF STEEL OR STEEL AND IRON combined		6,593	7,032	6,333
TOTAL OF IRON AND STEEL		1,738,629	1,752,432	1,991,270

DUTY-FREE CARGOES.—The importation of foreign ores into this country has been a good deal restricted at some ports, in consequence of the Customs regulations which prohibited the unloading of duty-free cargoes in bulk except during the day-time. An influential deputation of ironmasters and others waited upon Mr. Baxter at the Treasury a few months since, urging a modification of the regulations. The Treasury have recently intimated that in future duty-free cargoes in bulk may be unloaded continuously, provided the shipowners will pay the expenses of such extra Customs' officers as may be required.

DANKS'S ROTATORY PUDDLING FURNACE.—The Belgian iron manufacturers appointed a Commission to visit Great Britain, for the purpose of investigating the working of this furnace. Messrs. Hopkins, Gilkes, & Co., Middlesbrough, gave the Commissioners an opportunity of testing the machine in every way. The report of these gentlemen is understood to be of a favourable character. At the Institute Meeting in Glasgow, M. Taskin, one of the Commissioners, expressed a hope that a deputation from the Institute would attend the Annual Meeting of Belgian Engineers, to be held at Brussels in December next, and that at an early date the members of the Iron and Steel Institute would pay an official visit to the iron districts of Belgium.

INAUGURATION OF THE RAMSDEN STATUE AT BARROW.—The name of Sir James Ramsden is intimately associated with the development of the iron trade in the Furness district, and particularly with the rise and progress of Barrow as a seaport and commercial centre. At Whitsuntide last, the inhabitants of the district inaugurated with befitting formality, a statue in honour of this gentleman. The Duke of Devonshire took an active part in the proceedings on this occasion.

Manufacture of Iron and Steel.—In May last, Mr. Riley communicated to the Chemical Society a paper on this subject. The author confined himself chiefly to the influence of the elements associated with the pig, and the part they play in the subsequent conversion of the pig into wrought iron and steel.

Coal Beneath the Red Rocks in the Midland Counties. —At the annual meeting of the Dudley and Midland Geological Society, held in June, Professor Ramsay, Director-General of the Geological Survey, delivered an address on the "Existence of Coal beneath the New Red Sandstone and Permian Strata." In the course of his remarks, Professor Ramsay said he had for 15 years been working up this subject, previous to receiving an appointment on the Royal Coal Commission, and the opinions he should express were the result of a searching consideration. The coalfields of England were originally divided into two great divisions, one comprising the Northern and Midland coalfields, and the other the Devonshire, South Wales, Forest of Dean, Somersetshire, and continuous districts. Between these two great divisions there was no continuity of the coal measures, a great area of high land standing up between the north and south. On this high land some of the poorer measures might have been deposited, but it entirely lacked the rich deep measures belonging to the carboniferous era. Devonshire was, and would remain, an unproductive coalfield. In two borings through the Permian at Wassall Grove, near Halesowen, the thick coal was found, but the ordinary measures were wanting. It was highly probable, however, that ordinary coal measures underlie the district between the South Staffordshire boundary and the Forest of Wyre, and although much of it would not be profitable to work on the west side of the Staffordshire boundary towards Shropshire, coal, he fully believed, existed under the Permian strata. The lias and oolites once covered the whole of South Staffordshire. The Northern part of South Staffordshire, from Wyrley to Shifnal, also, he firmly believed, contained valuable coal, much of which was at a workable depth. The coal measures are undoubtedly continuous between South Staffordshire and the Warwickshire coalfield. In North Warwickshire, the coal, as you go north, is split up into seven or eight stratified bands of sandstone and shale. The coal of Shropshire is an actual representation of that of the south half of the South Staffordshire coalfield. This indentification

proves the continuance of the coal measures between the three districts of South Staffordshire, Shropshire, and North Warwickshire. The Warwickshire coalfield is in the shape of a basin, the coal underlying the Permian and New Red strata. Thence to the south end of South Staffordshire there is coal, but not profitable to work. In the north end the measures are, however, likely to be rich and valuable. The coal beds were also continuous, he believed, between Staffordshire and Leicestershire. From Old Wales to the Forest of Wyre there was profitable ground, and thence on to Charnwood Forest, but east of that, the coal measures were not of much value. Under other parts of the district lying beyond the recognised boundaries, valuable coal was also to be found. North of South Staffordshire, and between the mountainous limestone of Derbyshire, there must be important measures of coal at comparatively accessible depths. At the north-west end of Cannock Chase (on Lord Hatherton's estate), he would, without hesitation, sink for coal, Higher up in the county, and particularly in the neighbourhood of Uttoxeter, he had many reasons for believing in the existence of valuable coal. The estimated coal supply of South Staffordshire and Shropshire was now 3,201,000,000 tons. Assuming his theories to be only approximately accurate, an additional supply of 10,000,000,000 tons would be available. The present supply of Warwickshire was 458,000,000, and this would in like manner be increased by 2,494,000,000, or five times more than the present estimate. The estimated supply of the Leicester field was 836,000,000, and to this would be added 1,790,000,000. This applied not to those coalfields only, but to other parts of Great Britain. There were exceptions, as, for instance, South Wales, Bristol, Forest of Dean, and Somerset, where the coal lies in basins formed by the process of denudation, and all the outside coal had been destroyed. Lancashire, Derbyshire, and the Cheshire fields were undoubtedly once united, their sub-division being due to similar causes. Between the estuary of the Dee and the Mersey there was coal no doubt, though at an unworkable depth. The Midland coalfield was not so sub-divided, but formed one great basin of itself, only a small portion of which had yet, he believed, been turned to profitable account.

Gold Medal of Society of Arts.—The gold medal of the Society of Arts has this year been awarded to Mr. Henry Bessemer,

President of the Iron and Steel Institute, "for the eminent services rendered by him to arts, manufactures, and commerce, in developing the manufacture of steel."

NEW IRON WORKS AT MOSTYN.—Two blast furnaces have recently been started at Mostyn, North Wales, by the proprietors of the Mostyn Colliery, of which Mr. John Lancaster, M.P., is the senior partner.

THE CARBONIFEROUS LIMESTONE OF SOUTH DURHAM AND NORTH YORKSHIRE.—Mr. William Cockburn, of Upleatham, read a paper on this subject, at a meeting of mining engineers, held at Newcastle in July last. He stated that in 1871 the pig iron made in the North of England amounted to 1,884,239 tons, and as from 10 to 12 cwt. of limestone are required per ton of pig iron made, the limestone consumed in ironmaking alone would be about 1,036,331 tons. After describing the mineralogical and geological features of the limestone, he stated that the three great sources of limestone for use by the local ironmasters, were Weardale, Forcett, and Merrybent.

IRON ROLLING MACHINERY.—Mr. Perry, in a patent, taken out recently, for reversing the motion of the rolls used in iron and steel manufacture, combines a fly-wheel with the ordinary reversing gearing, in such a manner as to prevent the sudden shocks to the machinery which the ordinary reversing mechanism, as generally used, occasions. According to this invention, the ordinary reversing gearing is driven from a shaft worked by a pair of engines. On this shaft is a clutch and fly-wheel, the said fly-wheel rotating freely on the shaft. In using this invention, the machinery is started with the clutch described engaged with the fly-wheel, the said fly-wheel consequently partaking of the motion of the machinery. To reverse the rolls, the fly-wheel clutch is thrown out of gear, with the fly-wheel and the engines stopped. The machinery comes quickly to rest, the fly-wheel continuing its rotation. The rolls being reversed by the clutch of the ordinary reversing gearing, the engines are again started and the rotating fly-wheel re-geared to its shaft by the fly-wheel [clutch. By this arrangement, the full power of the engines, together with the momentum of the fly wheel, is available without any shock being given to the machinery by the reversal of its motion.

MANUFACTURE OF CHARCOAL IRON IN SOUTH STAFFORDSHIRE.—

Mr. Light has commenced the manufacture of charcoal pig iron near the town of Bilston.

THE IRON INDUSTRY OF CLEVELAND.—The Yorkshire Union of Mechanics' Institutes visited the Cleveland mining district in May last, when Mr. I. Lowthian Bell read a paper "On the Cleveland Ironstone,—its Discovery and its Influence on the Trade of the District." In the course of his remarks he gave the following statistics of the iron trade of the district:—The total annual make of pig iron in Great Britain may roughly be taken at six millions of tons, and for this the district known generally as that of Cleveand furnishes close on one-third. To produce this the neighbouring hills must supply nearly five millions of tons of ironstone, while the Durham collieries contribute something like an equal weight (five million tons) of fuel; and the hills in the west of the same county send down about one and a-half millions of tons of limestone. Thus—inclusive of a certain quantity of hematite ore—there must be put in motion, for the yearly production of this quantity of crude iron, something more than twelve millions of tons of raw materials. To this must be added a substance not usually regarded under the latter designation, but, in reality, as fully entitled to be so classed as the fuel we burn. This is atmospheric air; of which something like seven millions of tons are yearly driven in to our blast furnace by the constant exercise of a power equal, probably, to that of twelve thousand horses. The number of men engaged in the pig ironworks alone may be taken at about six thousand. For the mining of the ironstone required in its manufacture, about 10,000 workpeople find employment. The coal consumed at the blast furnaces will require, for its extraction and coking, say 20,000, and the limestone, used as a flux, absorbs the labour of 2,000 men. Thus, in round numbers, to cover labour incurred in transport, &c., the blast furnaces worked in connection with the ironstone of the Cleveland Hills, will require the personal attendance of not far short of 40,000 people. As is well known, the smelter's duty is confined to the production of a very crude substance, the mere raw material from which objects of cast or wrought iron have to be worked. In the subsequent stages of manufacture—that is, in our foundries, forges, and rolling mills—fuel is not less indispensable than it is in the blast furnace. Hence, with an abundance of pig iron, and the Durham coalfield

close at hand, it is not surprising that establishments adapted for converting the crude metal into these forms, fitting it for immediate application to human use, should have sprung up on all sides. I am not in possession of any data to enable me to speak with precision on the actual quantity of iron consumed in the production of cast iron goods in the North of England, *i.e.*, between the Tyne and the Tees. It cannot, however, I imagine, be far short of 250,000 tons per annum, in which case, probably, 7,500 tons of fuel, and the labour of something like 5,000 workmen, will be required by the iron founders of the district. By the latest returns, there are at the present time close on 2,000 puddling furnaces. This represents a power capable, when in full work, of turning out about 1,000,000 tons of malleable iron per annum, requiring the attendance of well on to 20,000 workmen, and probably, at least, 2,000,000 tons of coal. It would be very difficult, if not impossible, to form a correct estimate of the extent to which engineering establishments, iron shipbuilding yards, and other branches of industry, owe their rapid increase in the three northern counties to the existence of the ironworks of which I have just given a brief summary. It is obvious, however, that the mere demand for machinery, for fire-bricks, and for various other objects required in the construction of our furnaces, forges, and mills, must have afforded, and must continue to afford, employment for vast numbers of men. Inclusive of the collateral demand for labour, I have, I trust, given fair grounds for believing that to bring the minerals consumed in our ironworks, and to convert them into the forms in which they are delivered to commerce, not far short of 75,000 men and boys are engaged.

The author afterwards traced the history of the ironstone trade of Cleveland from the discovery of the ore down to the present time. The extent of the deposits was fully described.

Institute Meeting at Glasgow.—In noticing the proceedings at this meeting, we have omitted to state, that on the afternoons of Wednesday and Thursday, the works in the neighbourhood of Gartsherrie, Coatbridge, Monkland, Motherwell, Mossend, and Coltness were visited, special trains having been arranged by the Local Committee. On Thursday evening, the Local Committee entertained the Institute at a banquet, which was held in the Corporation Galleries, Bailie Bain in the chair. On Friday, the members

made an excursion down the Clyde. The industrial features of the river were described in a pamphlet that had been prepared by Mr. J. Mayer. The party were conveyed to the head of Loch Long, across to Tarbet, thence to the head of Loch Lomond, where dinner was provided; and they afterwards proceeded down the Loch to Balloch, when they took train for Glasgow and elsewhere. The Local Committee throughout the meeting made most excellent arrangements for the comfort and convenience of the members, and the excursion on Friday was a highly enjoyable termination of the proceedings. On Saturday, Bailie Bain, Vice-chairman of the Clyde Trust, invited a number of gentlemen connected with the Institute to a special trip down the Clyde and to the Kyles of Bute.

Discovery of Coal at Sandwell.—Some time ago a project was started for proving the beds beneath the Red Rocks, a little to the north-west of Birmingham. The proposal emanated from Mr. Henry Johnson, President of the South Staffordshire Institute of Mining Engineers, and was very warmly taken up in the immediate locality. About a fortnight ago, the sinkers came upon true coal measures; and there is good reason to suspect that at a reasonable depth the highly valuable coal beds of the Staffordshire field will be found. Should this be the case, a large area of productive coal measures will be added to the resources of the Staffordshire iron trade.

Explorations for Coal in the South of England.—An experiment of considerable interest is now being made in the South of England. A committee has been formed for the purpose of putting down a bore-hole to ascertain whether coal measures exist beneath the Wealden formation in this country. The requisite funds have been subscribed, and the work is in progress. It is well known that several eminent geologists maintain that coal exists underneath the English Wealden, just in the same way as it occurs on the other side of the Channel. At the recent meeting of the British Association at Brighton, this subject was fully discussed, and the place selected for the boring was visited. As the Weald was formally the principal ironmaking district in England, it is quite possible that it may again become an iron manufacturing centre, as large quantities of iron ore exist, and the discovery of coal at a workable depth would render these available.

British Association.—At the recent meeting held at Brighton, very few subjects of much interest to the iron or steel trades came up for discussion. In the Mechanical Section, the President, Mr. Bramwell, enlarged upon the necessity for economising fuel in manufacturing and domestic appliances. Doubtless a great deal remains to be done in this direction in some departments of the iron manufacture, and the address in question is therefore deserving special attention by all interested in the production of iron or steel.

Dormoy's Rotating Rabble.—A paper was to have been read on this subject at the Glasgow meeting, but it had to be withdrawn, owing to want of time. Mr. Paget had, however, arranged with Mr Ellis, of the North British Iron Works, Coatbridge, to erect two furnaces, with the rabble attached to each. These were in operation during the time of the meeting, and were visited by a considerable number of the members. Mr. Paget intends to bring the results of the working of those and other furnaces under the notice of the Institute at the next meeting.

Extensions in the Iron Trade.—In the North of England considerable extensions are going on. Near the mouth of the Tees, on the Yorkshire side, two new blast furnace firms are erecting works. At West Hartlepool, Messrs. T. Richardson & Sons are building two blast furnaces. In various parts of the district additions are being made to existing works. So that about twenty new blast furnaces are altogether in course of erection in this locality. The finished iron trade is being extended also. The North of England Industrial Iron Company, and the Erimus Iron Company are erecting furnaces on the Danks' principle—eighteen in all. At several other works also considerable additions are being made.

LIST OF DONATIONS.

The following is a list of publications presented to the Institute since May last :—

GUILDFORD SMITH.—Mineral Wealth and Railroad Development.

FORGE AND MILL MANAGERS' ASSOCIATION, MIDDLESBROUGH.—Rules.

FREDERICK A. PAGET, C.E.—Dormoy's Revolving Rabble in a Common Puddling Furnace.

ROYAL SOCIETY.—Proceedings, Vol. XX., Nos. 134 and 135.

MANCHESTER LITERARY AND PHILOSOPHICAL SOCIETY.—Meeting, March 8th, 1872.

THOMAS SCOTT.—Treatise on the Application of Zore's Truncated Iron to the Construction of Roofs, &c.

HENRY S. KING & CO.—Various numbers of the Mining Magazine and Review.

INSTITUTION OF MECHANICAL ENGINEERS.—Proceedings.

INSTITUTION OF CIVIL ENGINEERS.—Report of Speeches at Annual Dinner 24th April, 1872 ; Siemens on the Pneumatic Despatch Tubes ; Leslie on the Bridge over the Gorai River ; Abel on Explosive Agents ; Bell on the Stress of Rigid Arches ; I. Lowthian Bell on the Conditions which favour and those which limit the Economy of Fuel in the Blast Furnace in Smelting iron.

THE PUBLISHERS, 132, SOUTH SIXTH STREET, PHILADELPHIA, U.S.A.—The Penn Monthly (an American Magazine).

INSTITUTION OF ENGINEERS AND SHIPBUILDERS IN SCOTLAND.—Proceedings.

COMMISSIONERS OF PATENTS.—Abridgment of Specifications relating to the Steam Engine, Vol. I., 1618-1859 ; Vol. II., 1618-1859 ; Carriages and other Vehicles for Railways, 1807-1866 ; Music and Musical Instruments, 1694-1866 ; Production and Application of Gas, 1859-1866 ; Weaving, 1860-1866 ; Lamps, Candlesticks, &c., 1637-1866 ; Umbrellas, Parasols, and Walking Sticks, 1780-1866 ; Watches, Clocks, and other Timekeepers, 1857-1866 ; Needles and Pins, 1755-1866 ; Bricks and Tiles, 1861-1866 ; Chronological and Descriptive Index of Patents applied for and Patents granted April 1st to June 30th, 1870 ; July 1st to September 30th, 1870 ; October 1st to December 31st, 1870 ; January 1st to May 10th, 1871.

APPENDIX.

THE FORTHCOMING UNIVERSAL EXHIBITION AT VIENNA.

[At the request of the British Commission for the Vienna Exhibition, the Council of the Iron and Steel Institute publish the following particulars of the said Exhibition]:—

SOME time ago, Her Majesty, in pursuance of an invitation received from the Austrian Government, appointed a Royal Commission for the purpose of representing the British and Colonial exhibitors at the Universal Exhibition of Works of Industry and Agriculture, as well as of the Fine Arts, to be held at Vienna next year, under the immediate patronage of His Imperial and Royal Majesty the Emperor, His Imperial Highness the Archduke Charles Lewis, and a Commission, of which His Imperial Highness the Archduke Régnier has been appointed President.

His Royal Highness the Prince of Wales; Sir Andrew Buchanan, British Ambassador at the Court of Vienna; the Marquis of Ripon, K.G., Lord President of the Privy Council; Earl Cowper, K.G.; Lord Henry Gordon Lennox, M.P.; Lord Acton, and Henry Arthur Brassey, Esq., M.P., having been directly nominated members of the British Commission by Her Majesty, with power to appoint other persons to be Commissioners for the said Exhibition, they have at a recent meeting, in accordance with the authority vested in them, appointed His Serene Highness Captain Count Gleichen, R.N.; the Earl Cathcart, President of the Royal Agricultural Society of England, or the President of the Royal Agricultural Society of England for the time being; the Right Honourable Hugh C. E. Childers, M.P.; Sir Anthony de Rothschild, Bart.; Sir Richard Wallace, Bart.; Sir Francis Grant, President of the Royal Academy of Arts; Thomas Hawksley, Esq., President of the Institution of Civil Engineers, or the President of the Institution

of Civil Engineers for the time being, to be Royal Commissioners, in addition to, and together with them.

These Royal Commissioners have already held several meetings, and established their offices at 41, Parliament Street, where Mr. Philip Cunliffe Owen, the Secretary, will receive applications for space, and give every information as to the forwarding, exhibiting, and returning of the objects of the Exhibition in accordance with the regulations laid down.

All communications and applications must be addressed to the above office, where the general plans of the projected Exhibition, buildings, and adjacent parks can be inspected, and the rules and regulations to be observed may be obtained.

The Exhibition, as has been previously made known, will be held in the Prater—the Windsor Park of Vienna—in buildings erected especially for the purpose, and in the surrounding park and gardens.

It will be opened on the 1st of May, 1873, and closed on the 31st of October of the same year.

The general direction of the Exhibition has been entrusted by His Imperial Majesty to Privy Councillor Baron de Schwarz-Senborn, with whom Her Majesty's Commissioners are in direct correspondence. British exhibitors can communicate with the Austrian Commission solely through the Commission appointed for Great Britain and the Colonies.

Lists of the intended exhibitors of the United Kingdom and the Colonies, as well as detailed plans showing the space allotted, and of each single object to be exhibited, must be sent by the Royal Commission to the Director-General Baron Schwarz before the 1st January, 1873, at the latest, so that the exigencies of the respective countries may be taken into account in organising the interior arrangements of the exhibition buildings. As the total demand for space must depend upon the number of individual applications received, it is desirable that applications should be forwarded without delay to 41, Parliament Street.

The exhibition grounds will be considered as a bonded warehouse, goods for exhibition being exempt from custom duties, and objects which are monopolies in Austria may be exhibited without hindrance. The objects exhibited will likewise be protected against piracy of inventions or designs.

A special locality will be provided in the exhibition grounds

where exhibitors can sell publications relating to the Exhibition and to the objects which they exhibit (such as illustrated catalogues, list of prices, &c.)

Objects for exhibition will be admitted from the 1st of February until the 15th of April, 1873, inclusive.

The Director-General has entered into negotiations with the different railway and steam navigation companies of Austria and Hungary, and procured a considerable reduction of rates for the conveyance of objects for the Exhibition, and several of the English railway companies have already agreed with a praiseworthy spirit to offer the exhibitors from the United Kingdom similar facilities; other companies have the matter under consideration.

The Royal Commission having no public funds at its disposal, exhibitors will have to defray all expenses, including rental of space, transport of goods, and all other charges not provided for by the Imperial Austrian Commission. But there is no liability on the part of the exhibitors for ceilings, boarded floors, or the laying out of the gardens. The cost of these will be defrayed by the Imperial Commission.

The motive power for machinery will be supplied gratis.

Exhibitors of fine arts are exempted from any charge for space.

Foreign countries, we may even say all industrial states of the world, evince the greatest interest in this forthcoming Exhibition. In the East as well as in the West extraordinary preparations are being made to be well represented at this world's show. The East more particularly is desirous of sending its productions lavishly, and will make every exertion to compete successfully with the West. It is, therefore, highly desirable, and the wish of Her Majesty, as expressed in the Royal Commission, that England and her colonies should be well represented in art, science, and manufactures.

It has been said that Universal Industrial Exhibitions, regarded from a technical point of view, have outlived their day. The importance of the approaching Exhibition at Vienna cannot, however, be over-rated, considering the essentially civilizing influence of these grand and attractive gatherings. Hitherto these Exhibitions have occurred only in the great centres of civilization in the West of Europe, whereas the present Exhibition will take place on its extreme Eastern borders. To the east of Austria there is a population of some twenty-four millions of semi-civilized peoples

of European Turkey, including the Danubian Principalities, who, in view of the considerable extension of railways in progress into those distant parts through Hungary and Transylvania, will have an opportunity not before known of largely benefitting, by a more immediate contact with the Western civilization, in arts and sciences, in commerce, social habits, and customs. Besides that the great ends of national economy, of industrial and commercial speculation, will be greatly furthered by this enterprize, there is a political importance attached to this Exhibition.

Looking back upon the mighty results that have accrued to Great Britain and France from the Exhibitions of 1851, 1855, 1862, and 1867, the immense influx of strangers from far and near, the widened sympathies, the assimilation of new ideas and of foreign languages which resulted therefrom, it will be easy to conceive that the effects on the East of an International Exhibition in the Austrian capital can hardly fail to be much greater even than those realized in England and France. Hitherto the sympathies with this Exhibition have been rather lacking, it would seem, in England, and yet British interests are deeply involved. There is yet a vast market to be opened in European Turkey for agricultural implements, machinery of all kinds, cheap cloths, hardware, and many other British manufactures; and the enterprising capitalists would do well to direct their attention to the almost countless mineral treasures yet unexplored in Transylvania.

The situation of the Exhibition Palace is admirable, lying in the heart of a park unsurpassed for beauty by any in Europe. The area apportioned to the Exhibition will embrace about four to five English square miles. The covered space available for the Exhibition will be about 1,150,000 square feet, being considerably more than that occupied by the Paris Exhibition of 1867. The Exhibition building will be 905 metres long by 205 metres wide. It will contain one main gallery or nave intersecting the whole edifice. This gallery has cross galleries or transepts on each side, which are so placed as not to obstruct the view from either end. Between the transepts and the nave lie the garden courts, which will also be available for exhibition purposes, and each country will have one or more of these transepts allotted to it, together with the portion of the nave and the garden court adjoining. A rotunda will rise

from the centre of the building, and divide the main gallery in the middle. This rotunda, when finished, will be the largest canopy-shaped edifice without supports which has ever been erected. It has a diameter of 102 metres, and its height is 79 metres. The whole will be constructed of iron, after a design by Mr. Scott Russell.

The main gallery will be 25 metres wide, and each of the transepts 15 metres wide and 75 metres long. The latter are separated by courts, which are designed for such objects as can be exposed in uncovered places. The number of square metres within the Exhibition building will amount to 103,000.

East of the Prater Rondo, facing the main gallery, the Art Exhibition building will be erected, covering an area of 6,995 metres.

Buildings of a permanent character, sufficiently protected, will be provided for the exhibition of works of Fine Art.

From the chief building, covered galleries lead to a large conservatory, and to smaller pavilions, which are intended for the exhibition of horticultural productions, aquariums, &c. A separate hall will be erected for machinery in motion, 890 metres in length, and 28 metres in width. In this hall will also be found hydraulic machines, diving apparatus, &c.

The Imperial Villa, and the hall in which the jury will deliberate and make their awards, will also be erected in the grounds, which will be laid out under the direction of a landscape gardener of great reputation.

Groups 1 and 7 relate more particularly to the iron and steel trades :—

Group 1.

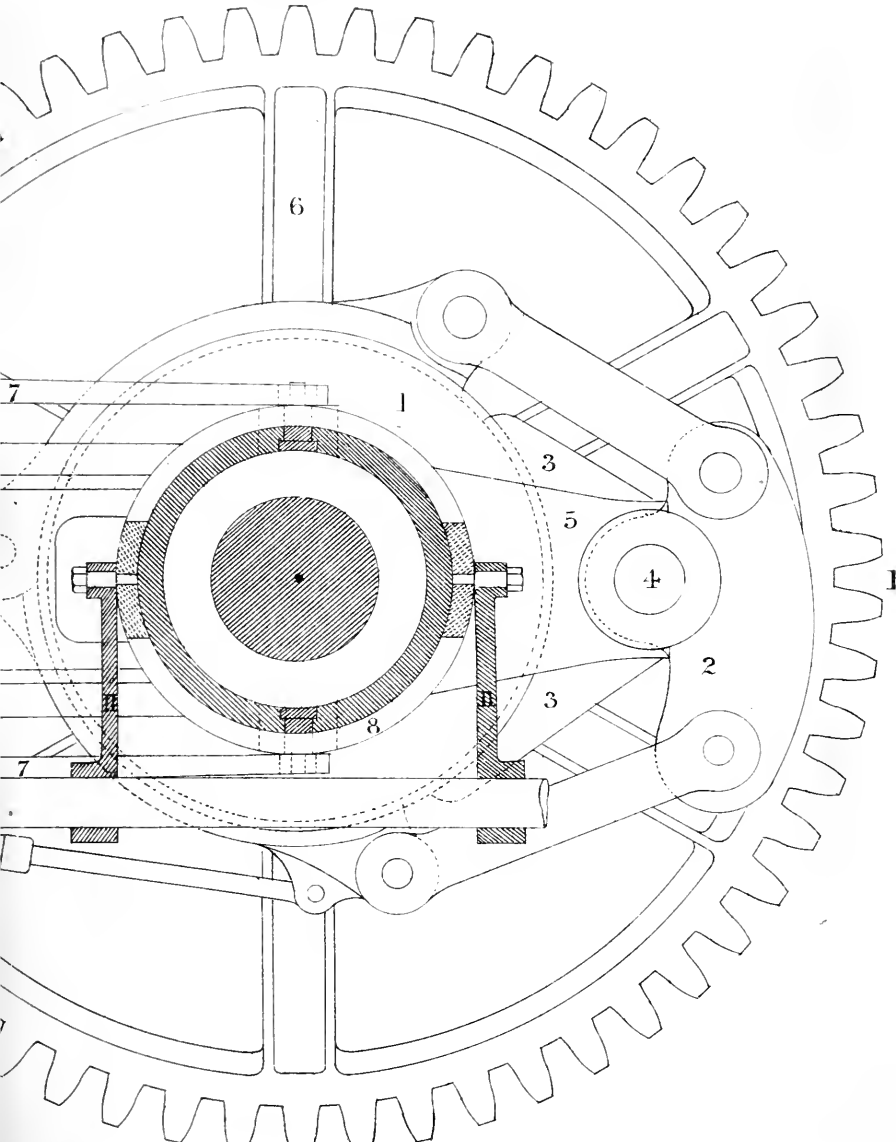
Mining, Quarrying, and Metallurgy.—(*a*) Mineral fuels (coals, shales, and mineral oils); (*b*) mineral ores and metals; (*c*) other minerals (as salt, sulphur, graphite, &c.); not including building materials; (*d*) natural alloys; (*e*) Drawings and models of objects relating to mining, metallurgy and mineral industry, mining engineering, surveying and map-making; (*f*) geological works and geological maps, &c.; (*g*) tools and inventions for mining and metallurgy, for under ground and surface work; (*h*) statistics of production.

Group 7.

Metal Industry.—(*a*) Goldsmith's and silversmith's work and jewellery, &c.; (*b*) iron and steel wares excluding machinery, building materials, philosophical and musical instruments; (*c*) manufactures from other metals and alloys; (*d*) weapons of every description except military arms; (*e*) processes and inventions used in the production of these manufactures; (*f*) statistics of production.

.UTCH

Fig 2.



M & M W Lambert, Newcastle

NAPIER'S PATENT REVERSING FRICTION CLUTCH

AS APPLIED TO

ROLLING MILLS.

To Illustrate M^r F. L. Napier's Paper

Fig 1.

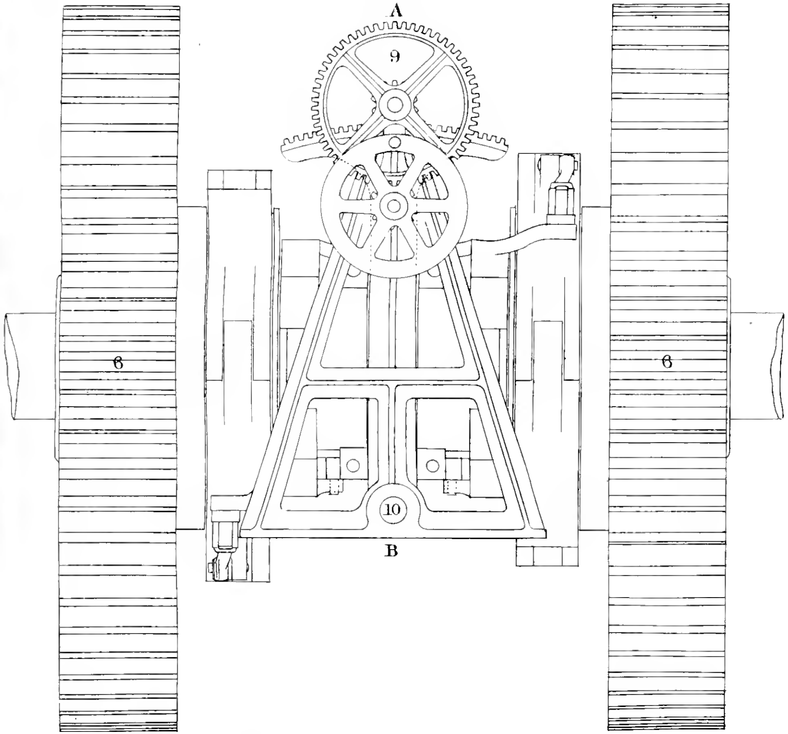
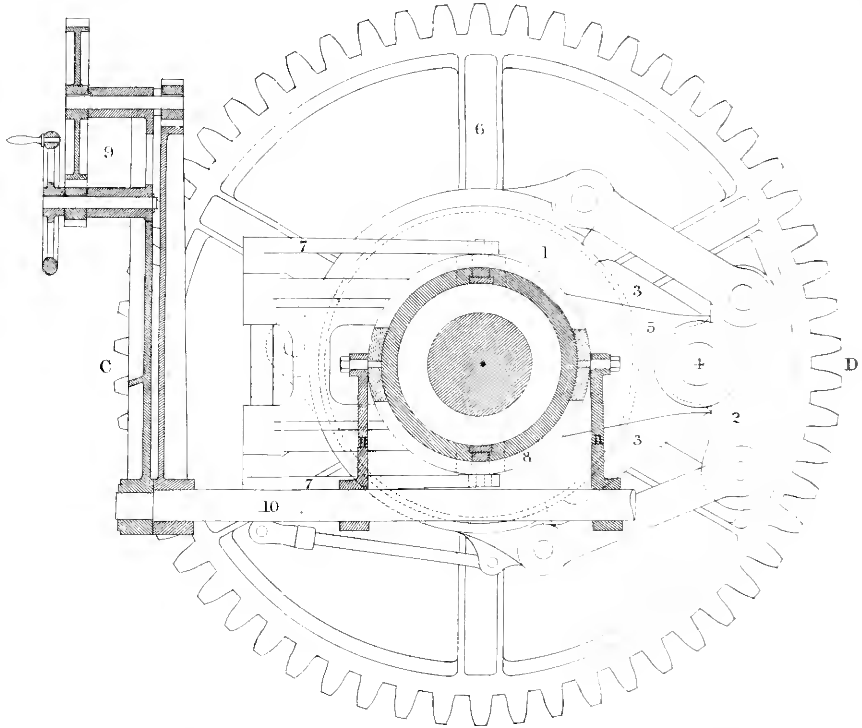


Fig 2.

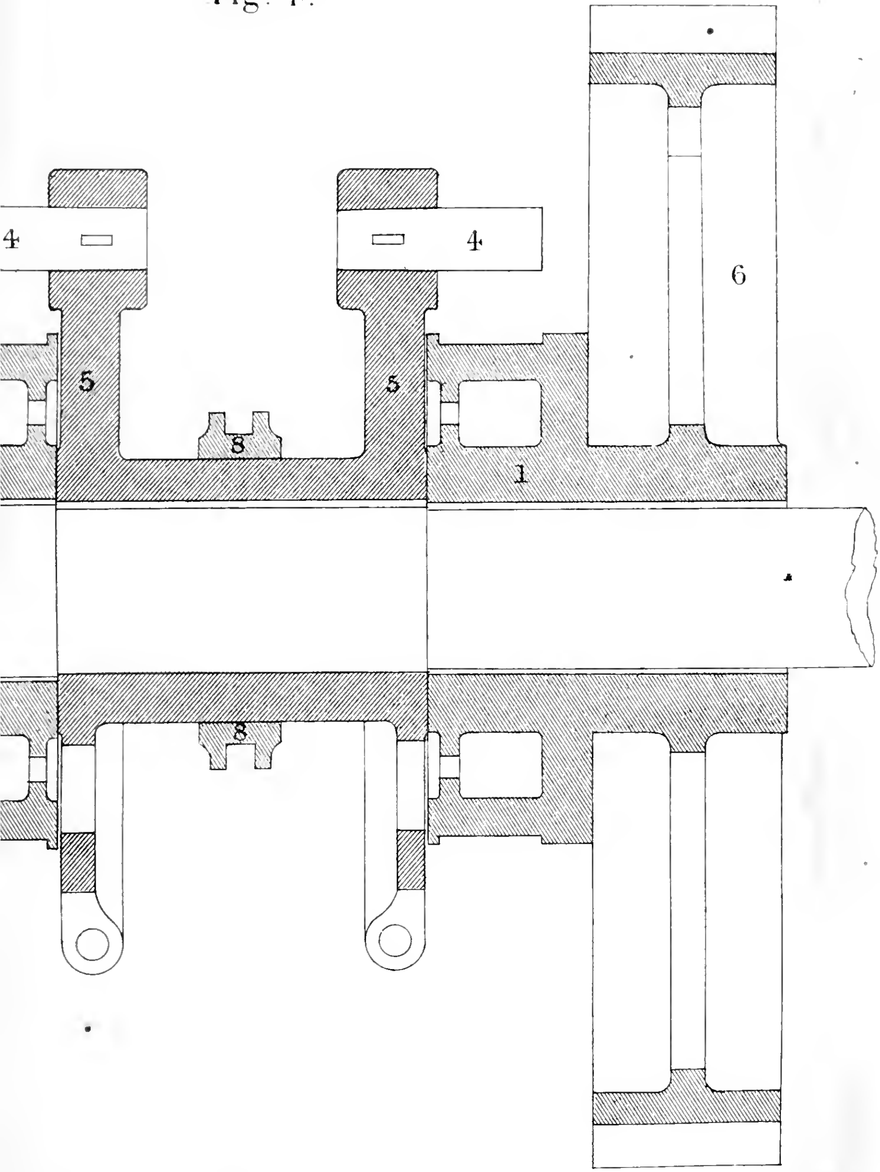


SCALE

Ins 12 6 0 1 2 3 4 Feet

UTCH

Fig. 4.



M & M W Lambert, Newcastle

NAPIER'S PATENT REVERSING FRICTION CLUTCH

AS APPLIED TO

ROLLING MILLS.

To illustrate M^r R. D. Napier's Paper

Fig. 3.

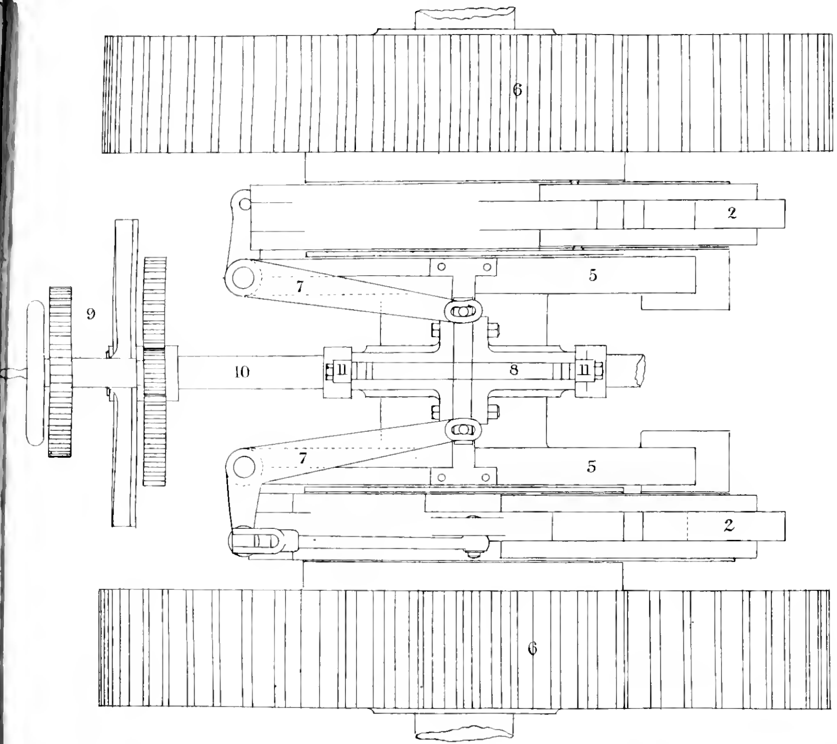
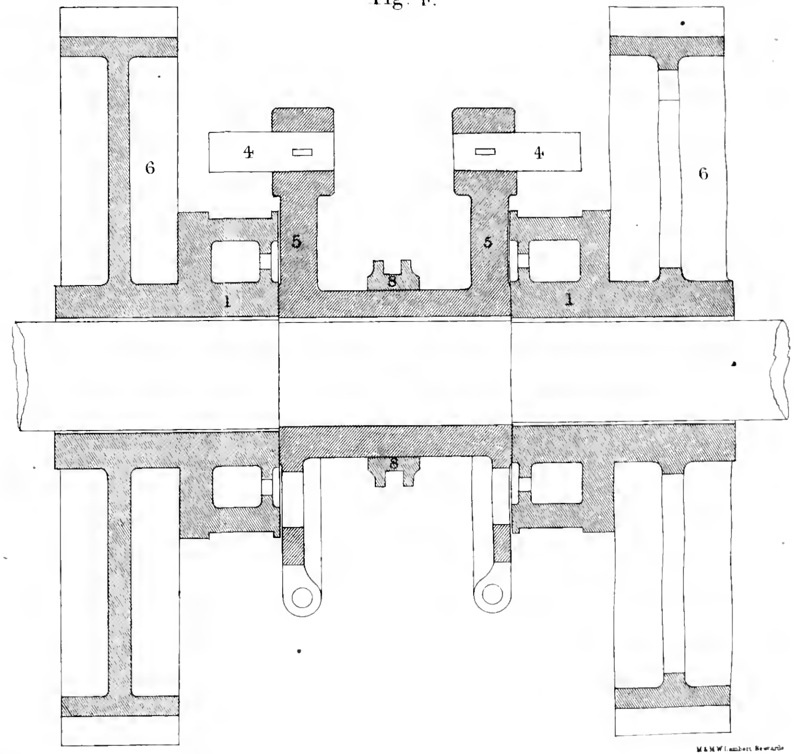


Fig. 4.



SCALE

Inches 12 6 0 1 2 3 4 Feet

M & M W Lambert Newcastle

NAPIER'S PATENT REVERSING FRICTION CLUTCH
AS APPLIED TO
ROLLING MILLS.

To illustrate M^r R.D. Napier's Paper

Fig. 5

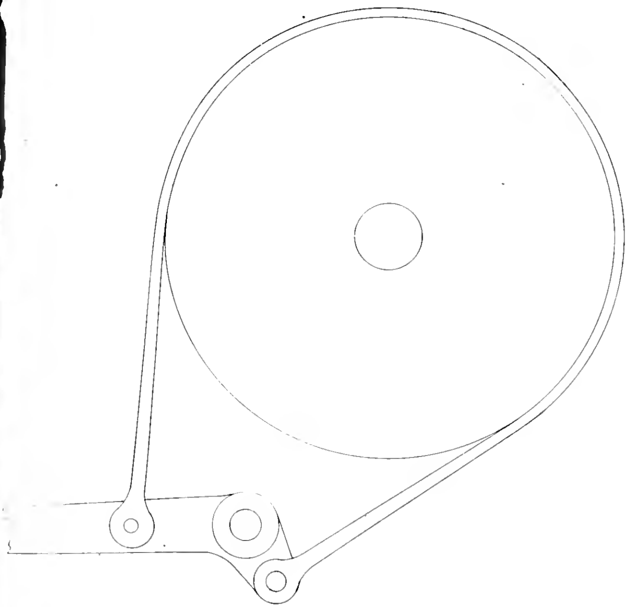
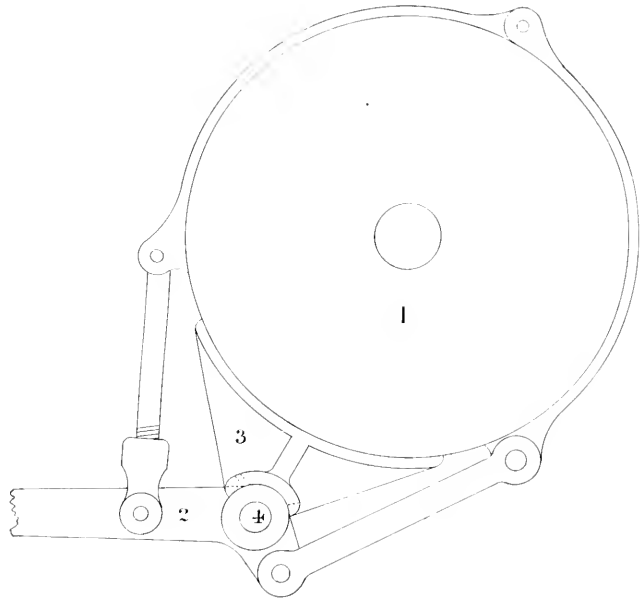


Fig. 6



M & M W Lambert, Newcastle

SES AND CONICAL CLUTCH.

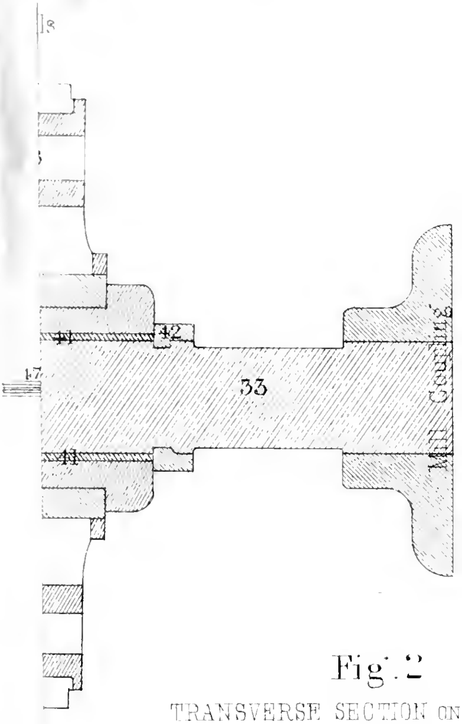
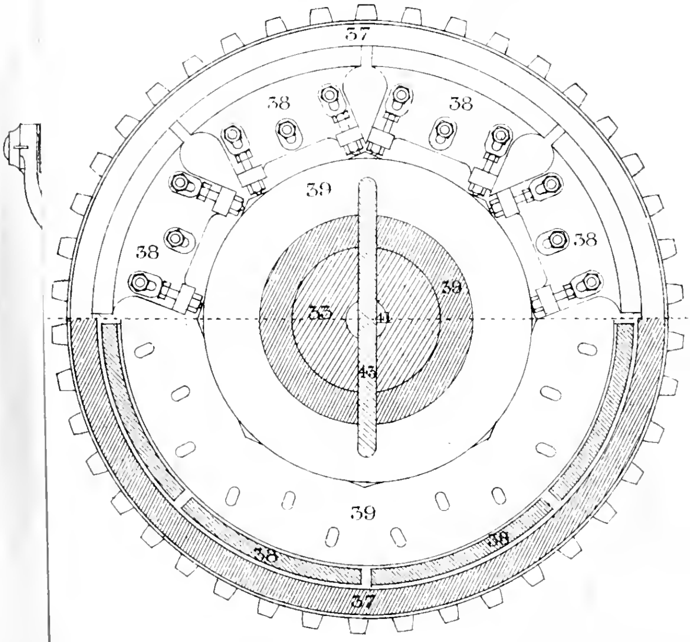


Fig. 2

TRANSVERSE SECTION ON LINE A B



SECTIONAL PLAN OF MILL SHAFT, GEAR-WHEELS AND CONICAL CLUTCH.

To illustrate Mr Stevenson's paper on "Reversing Rolling Mills"

Fig. 1

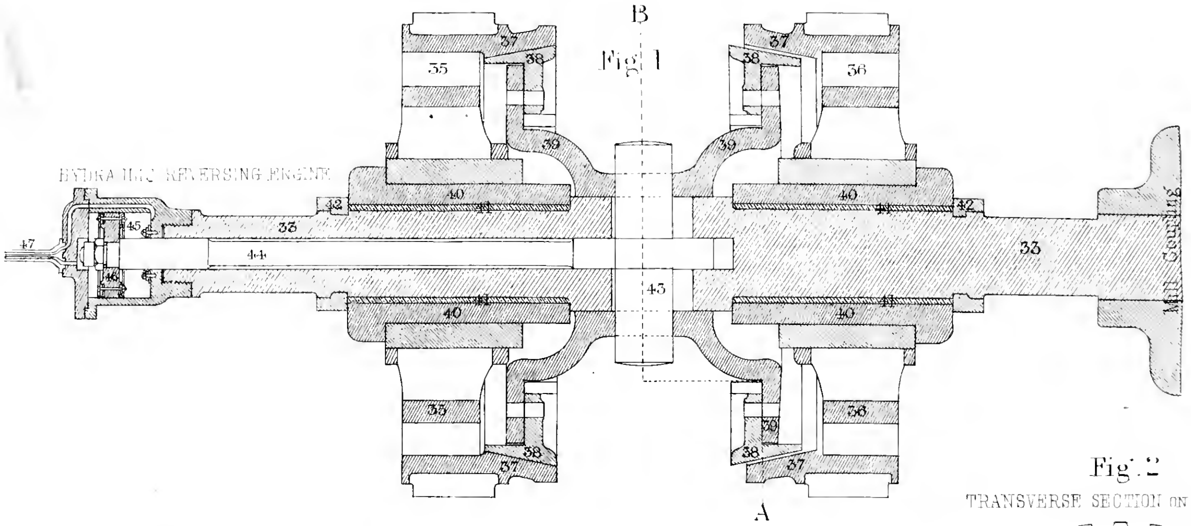


Fig. 2

TRANSVERSE SECTION ON LINE A B

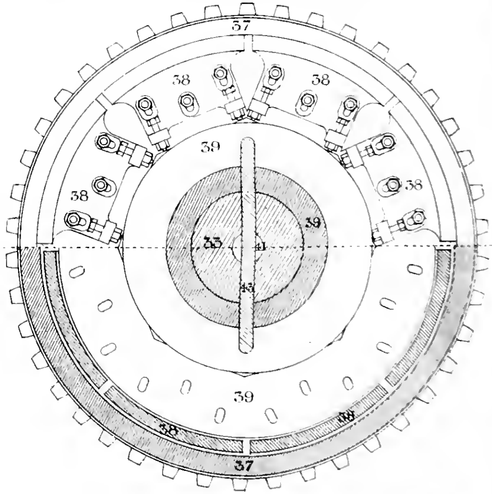
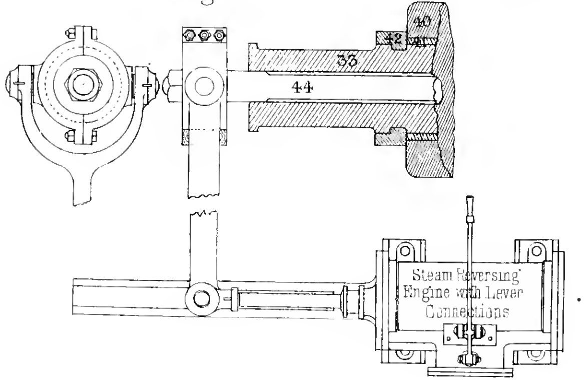
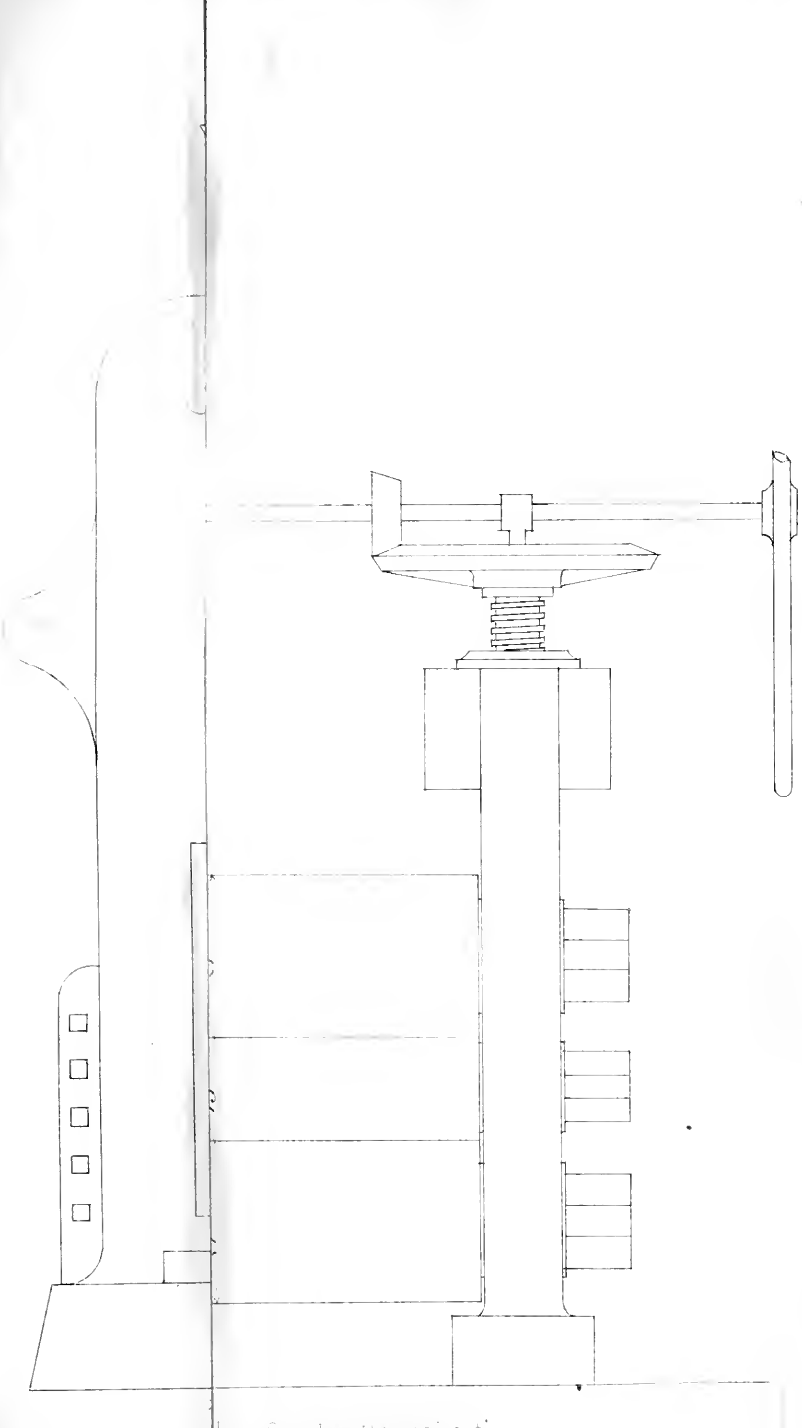


Fig. 3.



EET ROLLS.

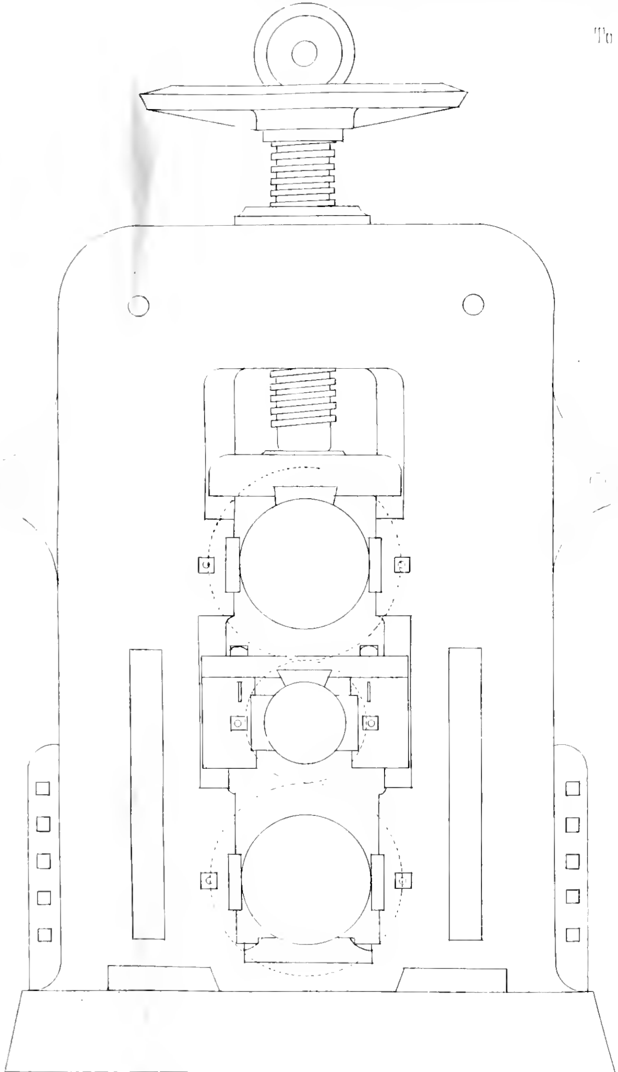


$\frac{1}{2}$ of an Inch to a foot

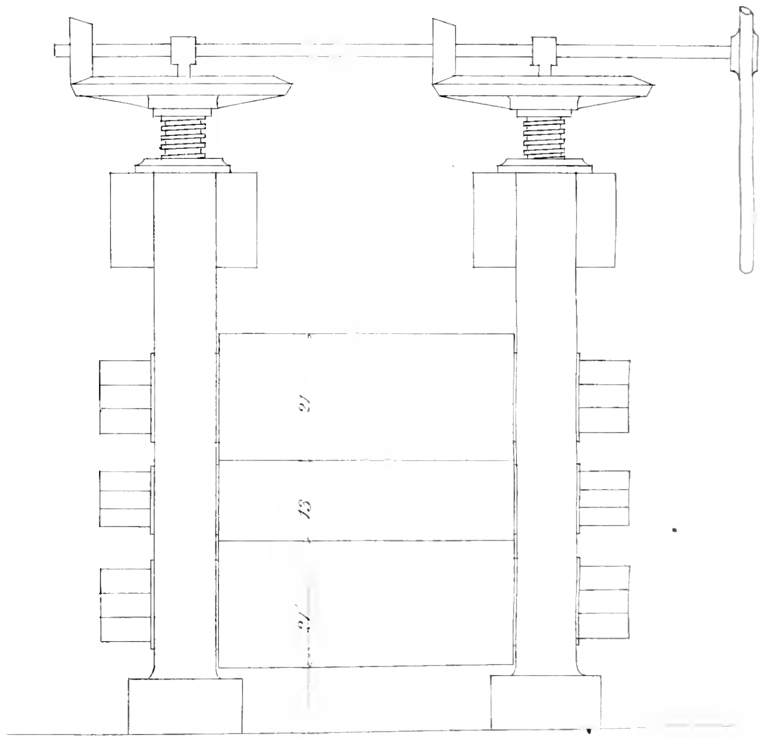
M & M W[illegible] Newcastle

LOUTH'S PATENT THREE-HIGH PLATE AND SHEET ROLLS.

To illustrate M^r B. G. Louth's paper



SCALE 3/4 of an Inch to One Foot

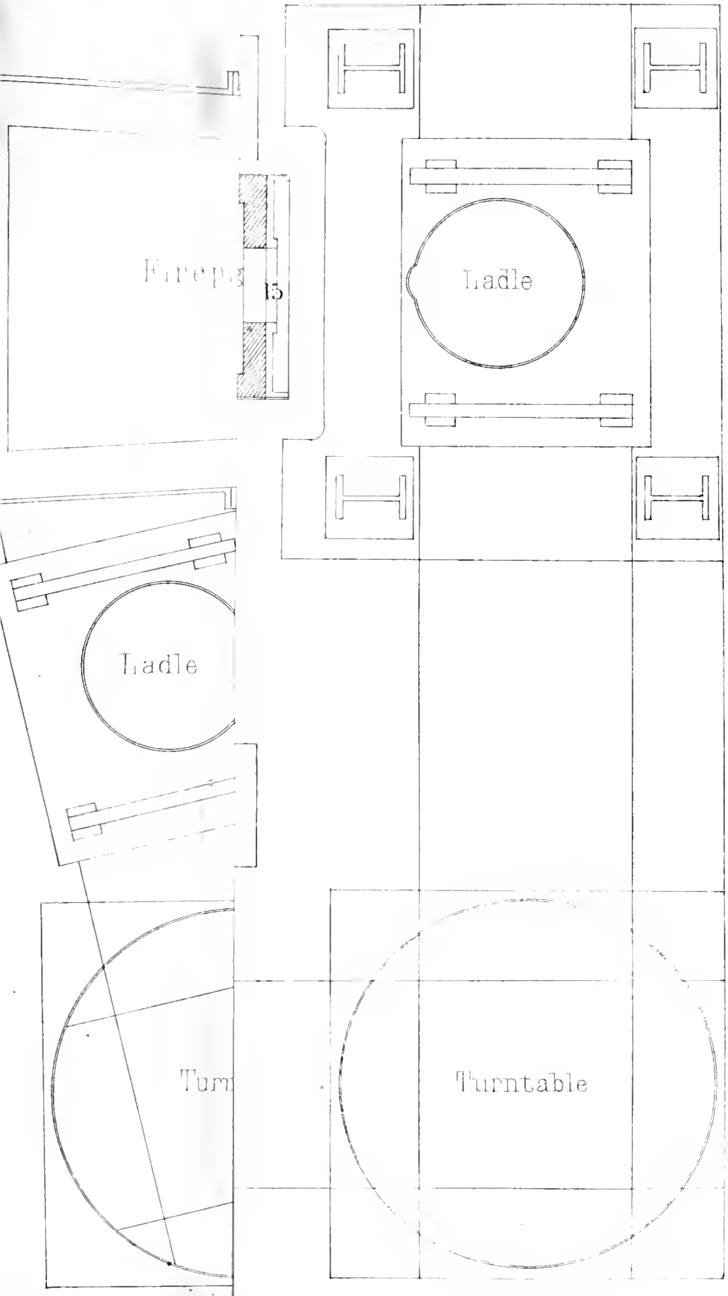


SCALE 1/2 of an Inch to One Foot

M & N Hanhart, lith.

MESSR. LING FURNACE.

DRAWING

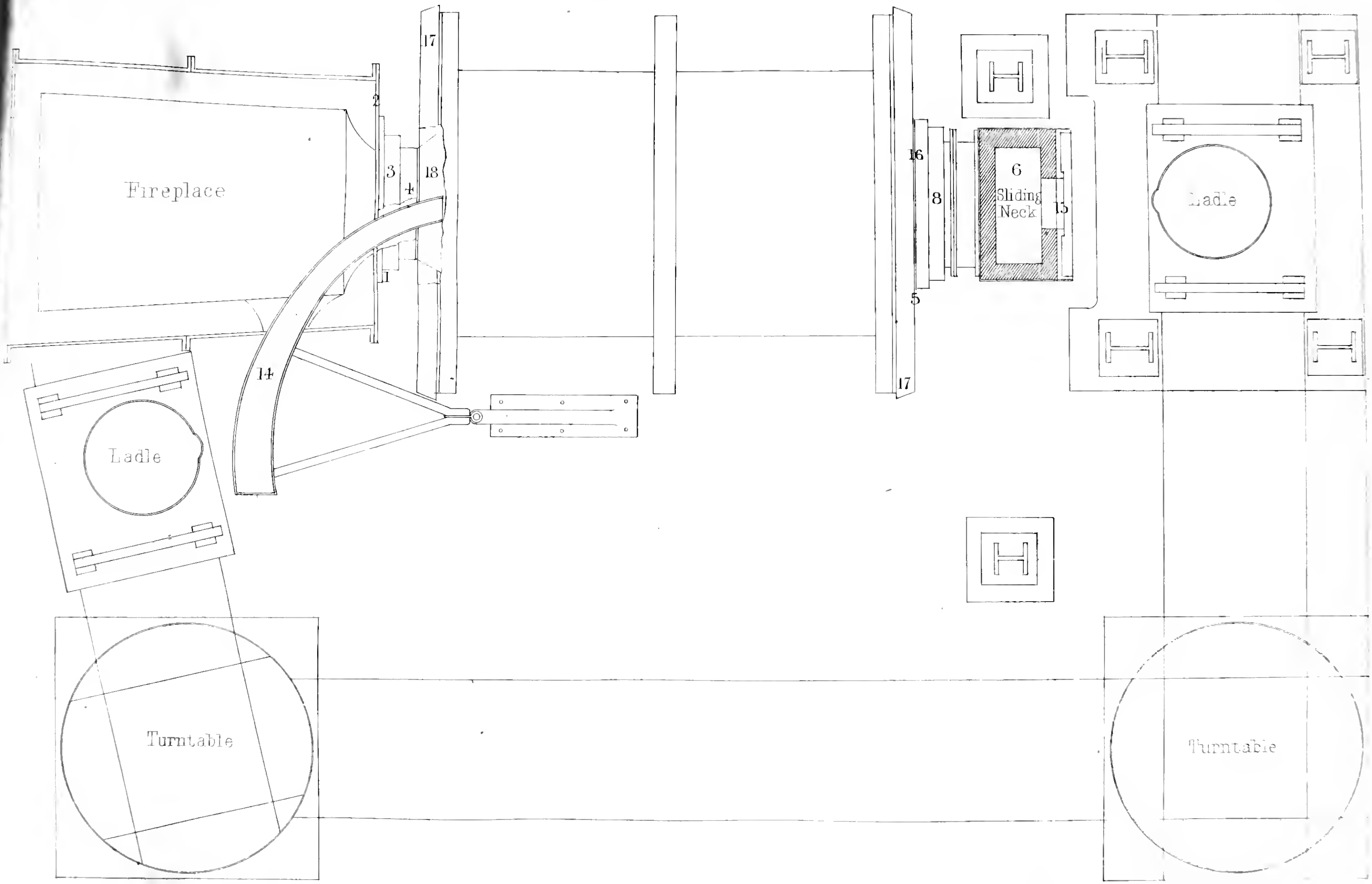


Journal of the

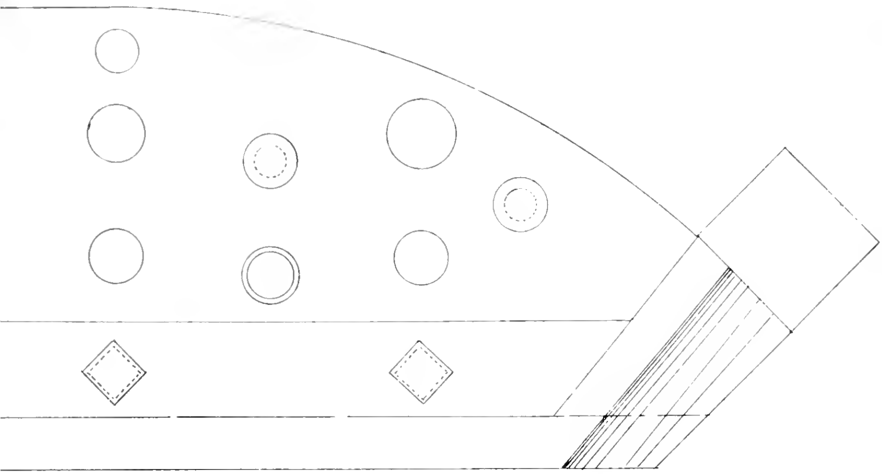
MESSRS. RICHARDSON AND SPENCER'S PATENT REVOLVING PUDDLING FURNACE.

DRAWING A

To illustrate Mr. A. Spencer's paper.



DLING FURNACE.

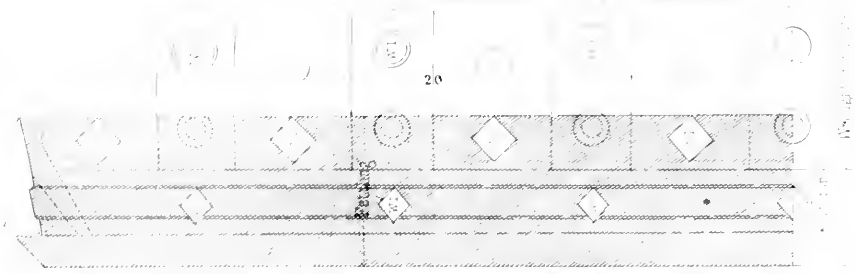


SIDE ELEVATION

MESS.RS RICHARDSON AND SPENCER'S PATENT REVOLVING PUDDLING FURNACE.

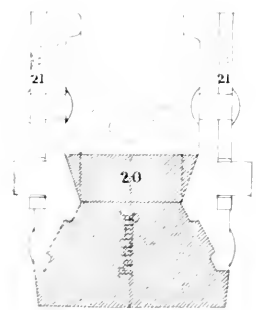
To illustrate Mr. A. Spencer's paper

DRAWING B



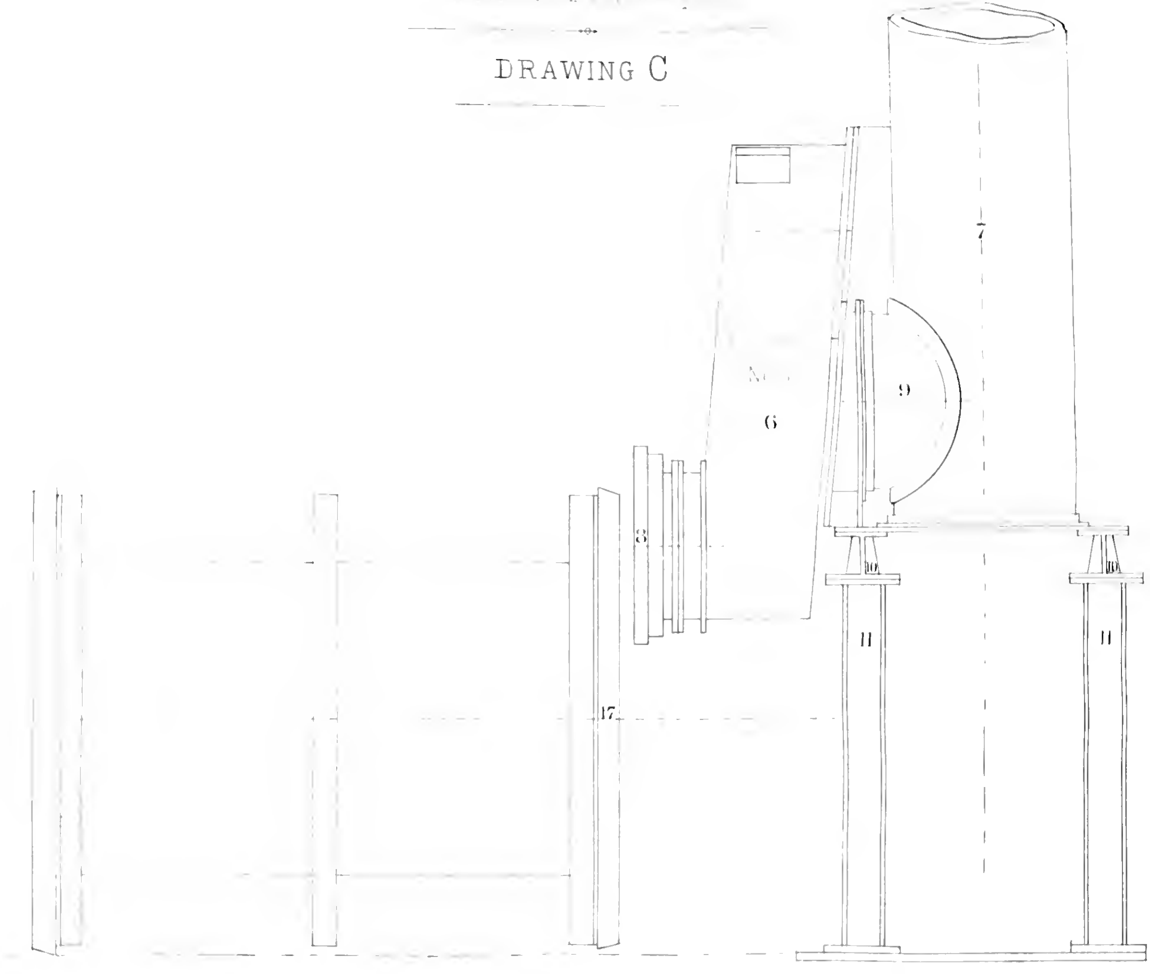
ELEVATION

HALF SIDE ELEVATION



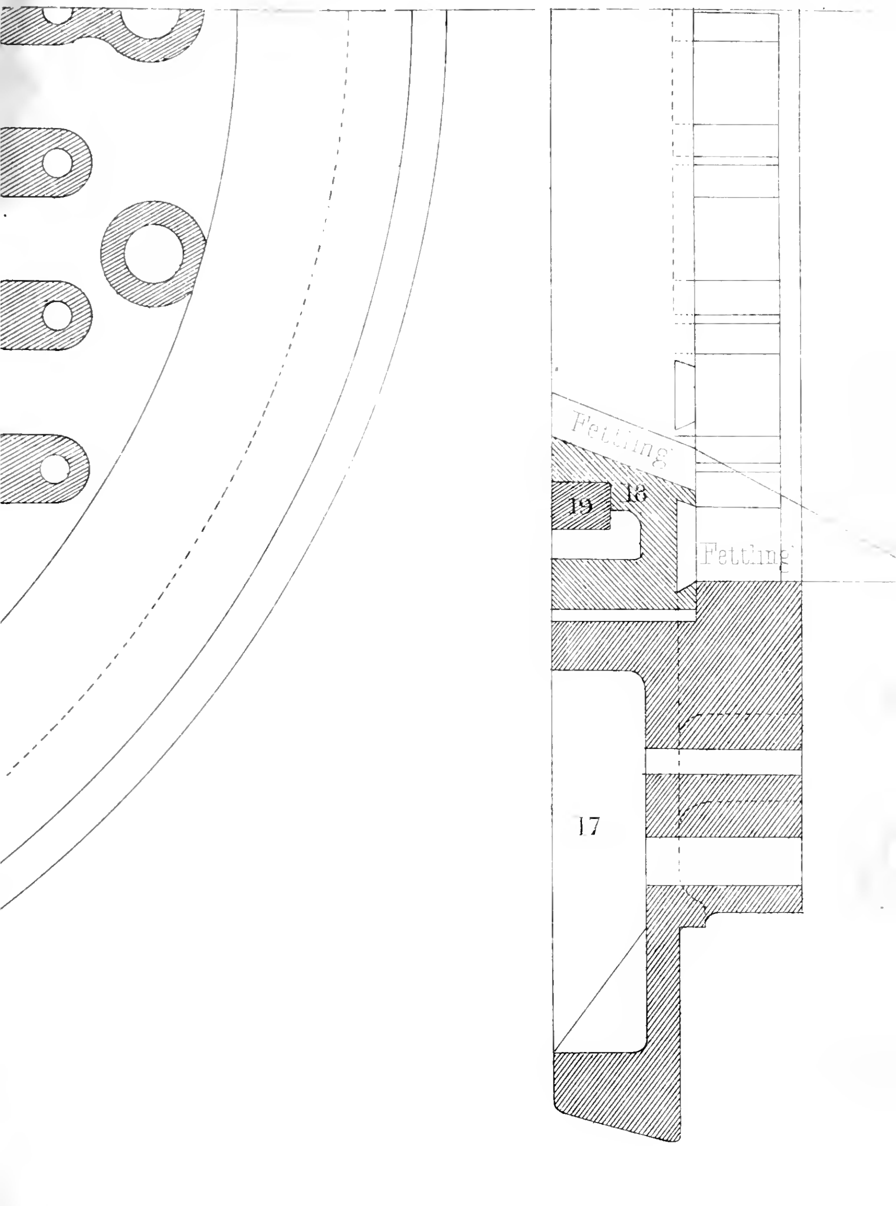
MESS.RS RICHARDSON AND SPENCER'S PATENT REVOLVING PUDDLING FURNACE.

DRAWING C



M & M W Lambert Newcastle

LING FURNACE.

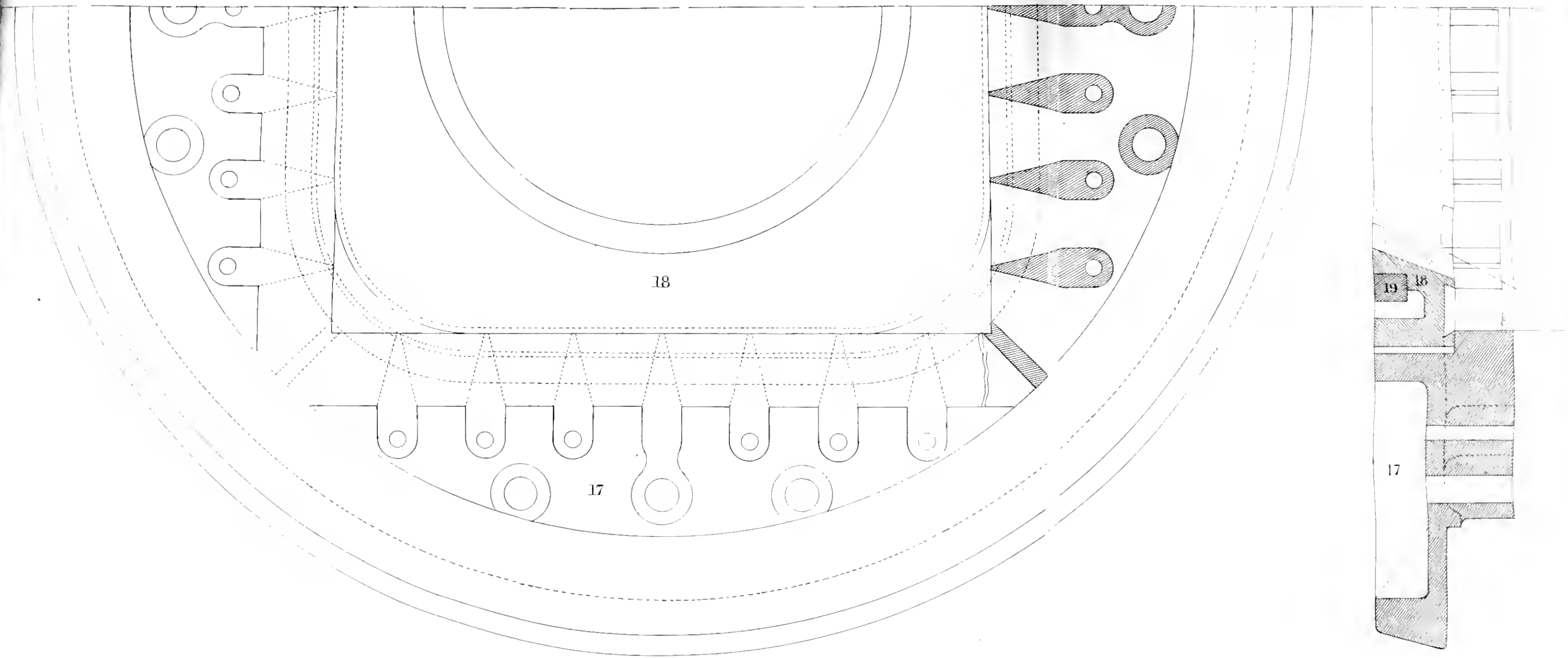


M & M W Lambert, Newcastle

MESS[RS] RICHARDSON AND SPENCER'S PATENT REVOLVING PUDDLING FURNACE.

To illustrate M[r] A Spencer's paper

DRAWING D



HALF ELEVATION OF INNER SIDE OF OUTER DISC

DUD DUDLEY'S

"METTALLUM MARTIS."

[By request, we reprint in this issue of the Journal, Dud Dudley's quaint work, published in 1665—*Mettallum Martis.* A copy in the British Museum has a note on the title page, probably in the handwriting of Sir John Pettus, Knight, of Suffolk, and one of the Deputy Governors of the Mines Royal, Anno 1641, to whom the volume belonged, stating that "1,000 were paid for, seller cheated of main, by Ironmasters." Several imperfect copies of the original work are preserved in the neighbourhood of Dudley. The book was reprinted in 1851 under the editorship of Mr. J. N. Bagnall, of West Bromwich.]

DUD DUDLEY'S "METTALLUM MARTIS."

That *Great Brittain* with her Men of Warr, Fleets and Shiping, have had in all Ages, and in these latter Ages, as great Success at Seas as any people whatsoever in the Universe, cannot modestly be denied in 88, overthrowing that Invincible Armado so long a preparing, and since other Navies also; and whose Armadoes, Navies, Armes, and Men, have been a Terrour to other Nations; nay her own Grand Magazins, are the very Granary from whence all His Sacred Majesties Kingdomes, Dominions, and Territories both in the *East* and *West-Indies*, on this side and beyond the Line, they have their whole and thorow supply of Shiping, Men, Armes, Food and Rayment, and more then can be, from any Kingdom of the Christian World.

Now if Wood and Timber should decay still, and fail, the greatest Strength of *Great Brittain*, her Ships, Mariners, Merchants, Fishings, and his Majesties Navies, and Men of War, for our Defence, and Offence would fail us, which before, and since 88 made his Sacred Majestyes Prodecessors, Queen *Elizabeth*, and her Great Council, the then Parliament, to make Lawes for the

preservation of *Wood* and *Timber*, especially near any Navigagable River; 1 *Eliz.* 15. 27 *Eliz.* 19. 28 *Eliz.* 3. 5. 23 *Eliz.* 5. All which Laws, and others, for the Preservation of Wood and Timber are still in force, but not duly Executed; also King *Iames* His Sacred Majesties Grand-father, and *Prince Henry* for the Preservation of Wood and Timber in this Island, did in the *9th* Year of His Reign, Grant His Letters Pattents of Priviledge unto *Simon Sturtevant,* Esq.; for 31 years, for the making of Iron with Pit-cole and Sea-cole for the preservation of Wood and Timber of *Great Brittain* so greatly then consumed by Iron-works; This Invention was by King *James's* command to be at large put in Print, which Book did contain near a quire of paper in quarto, called, *Simon Sturtevant* His *Metallica. Anno.* 1612. *May* 22. Printed by *George Eld, Cum Privlegio.*

After *Simon Sturtevant* could not perform his making of Iron with Pit-cole or Sea-cole, according unto his Engagement, King *Iames,* and Prince *Henry,* caused him to render up his Pattent, and a new Pattent was Granted unto *Iohn Rovenson,* Esq. who also was Enjoyned to write a Book of his Inventions, called *Rovenson's Mettallica.* Printed for *Thomas Thorp, Cum Privilegio: May* 15. *An.* 1613.

After *Iohn Rovenson,* Esq. had often failed with his Inventions, and great undertakings, *Gombleton,* Esq. a Servant of Queen *Ann's,* undertook (by Pattent) to perform the Invention of making of Iron with Pit-cole, and Sea-cole; but he being as confident of his Invention as others, did Erect his works at *Lambeth,* which the Author view'd; and *Gumbleton* failing, the Learned and Ingenious Doctor *Iordon* of *Baths,* the Authors Acquaintance, and sundry others obtained Pattents for the making of Iron, and melting of Mines with Pit-cole and Sea-cole, for the preservation of Wood and Timber all which Inventions and endeavours to Effect and Perfect the said Works, have been by many heretofore well known, to have worthily attempted the said Invention, though with fruitless success.

Having seen many of their failings, I held it my Duty to endeavour, if it were possible to Effect and Perfect so laudable, and beneficial, and also so much desired Inventions, as the making of Iron into cast Works and Bars; and also the Melting, Extracting, Refining and Reducing all sorts of Mines, Minerals and Metals, with Pit-cole,

Sea-cole, Peat, and Turf, for the preservation of wood and timber, so much exhausted by Iron Works of late.

Having former knowledge and delight in Iron Works of my Fathers, when I was but a Youth; afterwards at 20 years Old, was I fetched from *Oxford*, then of *Bayliol* Colledge, *Anno* 1619, to look and manage 3 Iron Works of my Fathers, 1 Furnace, and 2 Forges, in the Chase of *Pensnet*, in *Worcester-shire*, but Wood and Charcole, growing then scant, and Pit-coles, in great quantities abounding near the Furnace, did induce me to alter my Furnace, and to attempt by my new Invention, the making of Iron with Pit-cole, assuring my self in my Invention, the loss to me could not be greater then others, nor so great, although my success should prove fruitless; But I found such success at first tryal animated me, for at my tryal or blast, I made Iron to profit with Pit-cole, and found *Facere est addere Inventioni.*

After I had made a second blast and tryal, the fesibility of making Iron with Pit-cole and Sea-cole, I found by my new Invention, the quality to be good and profitable, but the quantity did not exceed above 3 Tuns *per* week: After I had brought my Invention unto some perfection, and profitable, doubted not in the future to have advanced my Invention, to make quantity also.

Immediately after my second tryal, I wrote unto my Father what I had done, and withall, desired him to obtain a Pattent for it from King *Iames* of Blessed Memory; the Answer to which Letter I shall insert, only to show the forwardness of King *Iames*, in this his much animating the Inventor, as he did both *Simon Sturtevant*, *Iohn Rovenson*, Doctor *Iordanie* and others; the Letter follows;

Son *Dudley*,

The Kings Majesty being at New-Market, *I sent* Parkes *thither on Saturday to some Friends of mine, to move the Kings Majesty for my Pattent, which be coming on Sunday Morning, in the Afternoon His Majesty sent a Warrant to Master Atturney to dispatch my Pattent, for the which I am infinitely bound unto His Majesty, that it pleased Him of His Great Grace and Favour to dispatch it so soon; I have been this night with Master Atturney, who will make hast for me; God Bless you, and Commend me unto all my Friends:*

March 10. Your Loving Father,
1619. *Edward Dudley.*

This *Richard Parkes,* à Parks-house Esq; in the Letter before mentioned, was the Authors Brother in Law, which did about 1 year after the *Pattent* was granted, carry for the Author much good Merchantable Iron unto the *Tower,* by King *Iames's* command to be tryed by all Artists, and they did very well approve of the Iron, and the said *Parkshouse* had a fowling Gun there made of Pit-cole Iron, with his name gilt upon the Gun, which Gun was taken from him by Colonel *Levison* Governour of *Dudley* Castle, and never restored.

The said *Richard Parkhouse's* son my Nephew, *Edward Parkshouse,* the 5th. of *Januaay* 1664, pressed me much to put Pen unto Paper, to shew what I have done in the invention of making of Iron with Pitcoale and Seacoal, not unknown unto this Country, and to my brother *Folliott,* Esq; and my Nephew *Parkshouse,* Esq ; and to my Kinsman Master *Francis Dingly,* to whom I intend to leave the Secrets of my Inventions, notwithstanding all my sad sufferings from time to time this forty Years in the invention, my Sufferings in the War, and my Estate sold for my Loyalty; and also my sad sufferings and obstructions since his Sacred Majesties happy Restauration many wayes; and also upon sundry and many references, at the Authors very great charge, pains, and time spent of Foure years in his aged dayes, for the general good, by his inventions for the preservation of Great *Brittain's* Wood and Timber.

Now let me shew some Reasons that induced me to undertake these Inventions, after the many failings of others, well knowing that withing Ten miles of *Dudley* Castle there to be neer 20000. Smiths of all sorts, and many Iron works at that time, within that Circle decayed for want of Wood (yet formerly a mighty Woodland Country.)

Secondly, The Lord *Dudley's* Woods and Works decayed, but Pitcoal and Iron, Stone or Mines abounding, upon his Lands, but of little Use.

Thirdly, Because most of the Coale Mines in these parts, as well as upon the Lord *Dudley's* lands, are Coals, Ten, Eleven, and Twelve yards thick; the top or the uppermost Cole, or vein, gotten upon the superficies of this Globe or Earth, in open works.

Fourthly, Under this great thickness of Coal, is very many sorts of Iron, Stone, Mines, in the Earth Clay or Stone earth, like bats

in all four yards thick; also under these Iron mines is severall yards thick of Coals, but of these in an other place more convenient.

Fifthly, Knowing that when the Colliers are forced to sinck Pits for getting of ten yards thick of Cole one third Part of the Coles or more, that be gotten under the ground, being small are of little or of no use in that inland Country nor is it worth the drawing out of the Pits, unlesse it might be made use of by making of Iron therewith into cast works or Bars.

Sixthly, Then knowing that if there could be any use made of the smal-coale that are of little Use, then would they be drawn out of the Pits, which coles produceth often times great prejudice unto the Owners of the works and the work it self, and also unto the Colliers, who casting of the smalcoles together, which compelling necessity enforcing the Colliers so to do, for two causes; one is to raise them to cut down the ten yards thicknesse of coles drawing onely the bigger sort of cole, not regarding the lesser or small cole, which will bring no money; saying, *He that liveth longest let him fetch fire further:* Next, These Colliers must cast these coles, and sleck or drosse out of their wayes, which sulphurious small cole and crouded moyst sleck heat naturally, and kindles in the middle of those great heaps; often fals the cole-works on Fire, and flaming out of the Pits, and continue burning like Ætna in Cicily, or Hecla in the Indies.

Yet when these loose Sulphurious compost of cole and sleck, being consumed in processe of time, the Fire decayes, yet notwithstanding the Fire hath continued in some Pits many years; yet colliers have gotten coles again, in those same Pits, the Fire not penitrating the solid and firme wall of coles, because Pabulum ignis est Aer, the Ayre could not penetrate, but passe by it in the loose cole and sleck; for comming into those pits afterwards, I have beheld the very blows of Pikes or tools that got the coles there formerly. Also from these Sulphurious heaps, mixed with Iron, Stone (for out of many of the same pits is gotten much Iron, Stone, Mines; the Fires heating vast quanties of Water, passing thorow these Soughs or Adits, becometh as hot as the Bath at Bathe, and more healing and soveraign even for old Ulcers and Sores; because many of these Baths doe proceed not onely from common Sulphur and vitriol of Mars, but also from Solar sulphur in this Iron stone; I hope, Filii Artis, will excuse my digesion from the making of Iron

with Pitcole, Seacole, Peat or Turff, and the melting of mines and mettals and refining of the same, with the like fuell: the first Pattent being granted by King Iames for 31, Years in the 19th year of his Reign upon just and true information, that the Authour had the year before made many Tuns of Iron with Pitcole at a Furnace or Ironwork, in the Chase of Pensnett, in the County of Worcester, besides cast Iron Works of sundry sorts with Pitcoles; and also at two Forges or Iron Mills, called, Cradly Forges, fined the said Iron into Merchantable good Bar Iron; But the year following, the grant or Pattent for making of Iron with Pitcole or Seacole, There was so great a Flood, by rain, to this day, called the great May-day-Flood, that it not onely ruinated the Authours Iron works, and inventions; but also many other mens Iron works: and at a market Town called Sturbridge in Commitate Wigorniœ, although the Authour sent with speed to preserve the people from drowning; one resolute man was carried from the Bridge there in the day time, and the nether part of the Town was so deep in Water that the people had much ado to preserve their lives in the uppermost rooms in their Houses.

My Yron works and inventions thus demolished, to the joy of many Iron maters, whose works scaped the Flood and who had often disparaged the Authours Inventions, because the Authour sold good Iron cheaper then they could afford it; and which induced many of the Iron masters to complain unto King Iames, averring, that the iron was not Merchantable; As soon as the Author had repaired his works and inventions (to his no small charge) they so far prevailed with King Iames, that the Authour was commanded with all speed possible, to send all sorts of Bar iron up to the Tower of London, fit for making of Musquets, Carbines and Iron for great Bolts, fit for Shipping, which Iron being so tryed by Artists and Smiths, that the iron masters and Iron-mongers were all silenced until 21th of King Iames: At the then Parliament, all Monopolies were made Null, and diverse of the Iron-masters endeavouring to bring the invention of making Iron with Pitcole, Seacole, Peat and Turff, within the compasse of a Monopoly; but the Lord Dudley and the Authour did prevaile; yet the Pattent was limited to continue but Fourteen years; after which Act the Authour went on with his invention cheerfully, and made annually great store of Iron, good and merchantable, and sold it unto diverse men yet living at

Twelve pounds per Tun; I also made all sorts of cast iron Wares, as Brewing-Cisterns, Pots, Morters, and better and cheaper than any yet were made in these Nations, with Charcoles; Some of which are extant to be seen by any man (at the Authours House in the City of Worcester) that desire to be satisfied of the truth in the Invention.

Afterwards, the Author was outed of his works and inventions before mentioned by the Iron-masters and others wrongfully, over long to relate: yet being unwilling his Inventions (having undergone much charge and pains therein) should fall to the ground, and be buried in him, made him to set forward his Invention again, at a Furnace called, Himley Furnace in the County of Stafford, where he made much Iron with Pit-cole, but wanting a Forge to make it into bars, was constrained for want of Stock to sell the Pig-Iron unto the Charcole Iron-masters, who did him much prejudice, not onely in detaining his stock, but also disparaging the Iron: Himley Furnace being Rented out unto Charcole Iron-Masters.

The Authour Erected a new large Furnace on purpose, 27 foot square, all of stone for his new Invention, at a place called, Hasco Bridge, in the parish of Sedgley, and County of Stafford; the Bellows of which Furnace were larger than ordinary Bellows are, in which work he made 7 Tuns of Iron per week, the greatest quantity of Pit-cole-Iron that ever yet was made in Great Brittain; near which Furnace, the Author discovered many new Cole-mines 10 yards thick, and Iron-Mine under it, according to other Cole-works; which Cole-works being brought unto perfection, the Author was by force thrown out of them, and the Bellows of his new Furnace and Invention, by riotous persons cut in pieces, to his no small prejudice, and loss of his Invention of making of Iron with Pit-cole, Sea-cole, &c. So that being with Law-Suites, and Riots, wearied and disabled to prosecute his Art and Invention at present, even untill the first Pattent was extinct: Notwithstanding the Author his sad Sufferings, Imprisonments wrongfully for several thousand pound in the Counter in London, yet did obtaine a new Pattent, dated the 2*d* of May, Anno 14. Caroli Primi of ever Blessed Memory, not only for the making of Iron into cast-works, and bars, but also for the Melting, Extracting, Refining and Reducing of all Mines, Minerals and Mettals, with Pit-cole, Sea-cole, Peat, and Turf, for the Preservation of Wood and Timber of this Island; into which

Pattent, the Author, for the better support and management of his Invention, so much opposed formerly at the Court, at the Parliament, and at the Law, took in David Ramsey, Esquire, Resident at the Court; Sir George Horsey, at the Parliament; Roger Foulke, Esquire, a Counsellour of the Temple, and an Ingenious Man; and also an Iron Master, my Neighbour, and one who did well know my former Sufferings, and what I had done in the Invention of making of Iron with Pit-cole, &c.

All which said Patentees, Articled the 11*th* of Iune following, the Grant not only to pay the Authour all the charges of passing the Pattent laid down by him, but also to lay in for a common and joynt-stock each man of the four, one hundred pounds, and so from time to time, what more stock any three of the Pattentees should think fit to be laid in for the making of Iron into cast works and bars, and likewise for the Melting, Extracting, Refining and Reducing of all Mines, Minerals, and Metals, with Pit-cole, Sea-cole, Peat and Turf, which Articles are yet extant.

Now let me without offence insert the opposition we all had, by means of powerfull Iron-Masters, with Sir Philibeard Vernat, a Dutch Man, and Captain Whitmore, who pretended much unto his late Sacred Majesty, but performed not their undertaking, which caused the Author, and his Partners thus to Petition.

To the King's Most Excellent Majesty.

The Humble Petition of Sir George Horsey Knight; David Ramsey, Roger Foulke, and Dud Dudley, Esquires:

Humbly Sheweth,

That whereas Your Petitioners being called before the Right Honourable, the Lord Keeper by Your Majesties Appointment, touching the making of Iron with Pit-cole, Sea-cole, Peat and Turf, for which they have Your Majesties Pattent; and seeing that Sir Philibeard Vernat, and Captain Whitmore, who are not Inventors, have obtained a Pattent also for the same; yet before their Pattent Granted, Sir Philibeard was ordered at Council-board, according to his Great Undertaking, to perfect his Great Undertaking and Invention within Two Years, and there hath been near Three Years passed, and yet have made little or no Iron: still he Opposeth Your Petitioners, and doth neither benefit himself, but hinders Your Majesty, and the Kingdom.

The reference unto the Petition followeth; At the Court at Greenwich, May 20th, 1638. His Majesty is pleased to refer this Petition to Master Atturney, and Master Solicitor General, to call the Petitioners before them, and to compose the differences between them; (if they can) or otherwise, to certifie his Majesty their opinions therein:

Sir Sidney Mountegue was then
Master of the Requests.

But Sir Philibeard Vernat, and Captain Whitmore never appeared any more for their Invention.

Not long after the Wars came on, and caused my partners to desist, since which they are all dead, but the Author, and his Estate (for his Loyalty unto his late Sacred Majesty) and Master, (as by the Additional Act of Parliament may appear) was totally sold.

Yet nevertheless, I still endeavoured not to bury my Tallent, took in two Partners into my inventions, Walter Stevens of Bristow Linnen Draper, and John Ston of the same City Merchant, after the Authour had begun to Erect a new work for the Inventions aforesaid, near Bristow, Anno 51, and there we three Partners had in stock near 700l. but they not only cunningly drew me into Bond, entered upon my Stock and Work, unto this day detained it, but also did unjustly enter Staple Actions in Bristow of great value against me, because I was of the Kings Party; unto the great prejudice of my Inventions and Proceedings, my Pattent being then almost extinct: for which, and my Stock, am I forced to Sue them in Chancery.

In the interim of my proceedings, Cromwell, and the then Parliament, granted a Pattent, and an Act of Parliament unto Captain Buck of Hampton Road, for the making of Iron with Pitcole and Sea-cole; Cromwell, and many of his Officers were Partners, as Major Wildman and others; many Doctors of Physick, and Merchants, who set up diverse and sundry Works, and Furnaces at a vast charge, in the Forrest of Dean, and after they had spent much in their Invention and Experiments, which was done in spacious Wind-Furnaces, and also in Potts of Glass-house Clay; and failing afterwards, got unto them an Ingenious Glass-Maker, Master Edward Dagney an Italian then living in Bristow, who after he had made many Potts, for that purpose went with them into the Forrest of Dean, and built for the said Captain Buck and his Partners, a new Furnace,

and made therein many and sundry Experiments and Tryals for the making of Iron with Pit-cole and Sea-cole, &c. But he failing, and his Potts being all broken, he did return to Bristow frustrate of his Expectation; but further promising to come again, and make more Experiments; at which time Master John Williams, Master Dagneys, Master of the Glass-House was then drawn in to be a Partner for 300l. deposited, and most of it spent, the said Williams and Dagney hearing that the Authour had knowledge in the making of Iron with Pit-cole, Sea-cole, &c. they from Cap. Buck, and the other Partners importuned the Author, who was at that time in great danger by the Parliament, (being a Colonel of the Kings Party) to go along with them into the Forrest of Dean, which at that time durst not deny; Coming thither, I observed their manner of working, and found it impossible, that the said Edward Dagney by his Invention should make any Iron with Pit-cole or Sea-cole, in Pots to profit: I continued with them till all their Potts and Inventions failed; at every Dinner and Supper, Captain Buck, Captain Robins, Doctor Ivie, Doctor Fowler and others, would aske the Author why he was so confident that Iron in quantity could not be made by their new Inventions? I found it a difficult thing to disswade the Partners from their way, so confident were they to perform the making of iron with Pit-cole or Sea-cole to profit; that they desired me to come again a second time into the Forrest to see it Effected; But at that time, I saw their failings also.

Yet nevertheless Captain Buck, and his Partners Erected new Works at the City of Bristow, in which they did fail as much as in their former Inventions; but Major Wildman, more barbarous to me than a Wildman, (although a Minister bought the Authors Estate, near 200l. per Annum, intending to compell from the Author his Inventions of making of Iron with Pit-cole; but afterwards passed my Estate unto two Barbarous Brokers of London, that pulled down the Authors two Mantion Houses; sold 500 Timber Trees off his Land, and to this day are his Houses unrepaired.

Anno 1655. Captain Buck and his Partners wearied of their Invention, desisting, An. 1656. Captain John Copley from Cromwell obtained another Pattent for the making of Iron with Pit-cole and Sea-cole; He and his Partners set up their Works, at the Cole-Works near Bristow, and endeavour'd by Engeneers assistance to get his Bellows to be blown, at, or near the Pits of Cole, with which

Engines the Work could not be performed: But the Author coming to see the said Works, and after many Discourses with Captain Copley, his former Acquaintance, told him plainly, if his Bellows could have been blown by those Engines, yet I feared he could not make Iron with Pit-cole or Sea-cole; he seemed discontented; whereupon, and without those Engines I made his Bellows to be blown feisibly, as by the Note under his hand appears (the first Note) followeth;

1656. December 30.

Memorandum, The day and year above-written, I John Copley of London, Gent. Do acknowledge, that after the Expense of diverse Hundred Pounds to Engineers, for the making of my Bellows to blow, for the making of Iron with Pit-cole or Sea-cole near Bristow, and near the Forrest of Kings-wood; that Dud. Dudley, Esq. did perform the blowing of the said Bellows at the Works or Pits abovesaid; a very feisible and plausible way, that one man may blow them with pleasure the space of an hour or two; and this I do acknowledge to be performed with a very small charge, and without any money paid to him for the same Invention:

John Copley.

Captain John Copley thus failing in his Inventions, An. 1657, he went into Ireland, and all men now desisting from the Inventions of making of Iron with Pit-cole and Sea-cole: The Author, Anno 1660. being 61. years of Age, and moved with pitty, and seeing no man able to perform the Mastery of making of Iron with Pit-cole, or Sea-cole, immediately upon his Sacred Majesties happy Restauration, the same day he Landed, Petitioned that he might be restored to his place, and his Pattent obstructed, revived for the making of Iron with Pit-cole, Sea-cole, Peat and Turf, into cast Works and Bars, and for the Melting, Extracting, Refining and Reducing of all Mines, Mettals and Minerals, with Pit-cole, Sea-cole, Peat and Turf; which said Laudable Invention, the Author was and is unwilling should fall to the ground and dye with him, neither is the Mistery, or Mastery of the Invention Effected and Perfected by any man known unto the Authour, as yet, either in England, Scotland or Wales; all which three abound with Pit-cole or Sea-cole, and do overmuch furnish other Kingdomes many with Pit-cole and Sea-cole, when they might make far better use of it themselves, especially Scotland and Wales, both for the making of

Iron into cast Works and Bars; and also for the making of Steel, and Melting, Extracting, and Refining of Lead, Tin, Iron, Gold, Copper, Quicksilver, and Silver, with Pit-cole, and Sea-cole.

I shall not trouble you with the Petition, or my reasons and desires that were annexed unto it, for the making of Iron, and Melting of Mines, &c. with Pit-cole, &c. they are over long to relate, only the Reference to them is thus; (after my first Petition was lost, I Petitioned again.)

At the Court at Whiteh. 22. of June 1663.

His Majesty is graciously pleased to refer the consideration of this Petition to Master Atturney, and Solicitor General, or to either of them, together with the Petitioners Reasons and Desires hereunto annexed; and they, or either of them, are to inform, and certifie His Majesty, what they, or either of them in their Judgements respectively conceive fit for His Majesty to do concerning the Petitioners Humble Request, and then His Majesty will declare his further pleasure.

Robert Mason, Ma-
ster of Requests.

After Master Atturney, and Sollicitor General would do nothing upon the Reference; the Author Petitioned His Sacred Majesty sitting at the Council-Board, for the Renewing of his Pattent, for making of Iron, and Melting, of Mines with Pit-cole, Sea-cole, often obstructed; the reference to that Petition followeth.

At the Court at Whitehall, July 25. 1660.

Upon reading of a Petition this day at the Board, being the same in terminis with this above-written, which His Majesty was graciously pleased by a Reference under the hand of Doctor Mason, one of the Masters of the Requests, to refer to the consideration of Master Atturney, and Master Solicitor General, together with the Petitioners Reasons and Desires thereunto annexed, to the Consideration of the Lords, and others Commissioners for the Treasury, who upon Examination of the particulars, are to give such order thereupon, as they shall find most proper for His Majesties Service.

Sir Edward Walker was
Clark to the Council, and
Garter King at Armes.

The Author, during the Lords Commissioners their time, could get no Order upon his Reference; But his Petition was left, with

the now Right Honourable, the Lord Treasurer, to take or grant further order therein, but the Author hath gotten hitherto no order.

Therefore compelling necessity doth constrain (having prosecuted his Petition hitherto) him to desist from his Inventions, in which he hath taken more pains, care and charge, then any man, to perfect his new Invention in these Kingdomes.

Although the Author hath not as yet so fully perfected or raised his invention, to the quantity of Charcole Iron Furnaces, yet the Authors quantity being but seven Tuns per week at the most, together with the quality of his Iron made with Pit-cole and Sea-cole, hath the most eminent Triplicity of Iron of all that can be desired in any new Invention.

1. More Sufficient. 2. More Cheap. 3. More Excellent.

Upon which triplicity, the Authour might enlarge himself, but shall not be tedious, only give me leave to mention that there be three sorts of Cast Iron;

1. The first sort is Gray Iron.

2. The second sort is called Motley Iron, of which one part of the Sowes or Piggs is gray, the other part is white intermixt.

3. The third sort is called white Iron, this is almost as white as Bell-Mettle, but in the Furnace is least fined, and the most Terrestrial; of the three, the Motley Iron is somewhat more fined, but the Gray Iron, is most fined, and more sufficient to make Bar-Iron with, and tough Iron to make Ordnance, or any Cast Vessels, being it is more fined in the Furnace, and more malliable and tough, then the other two sorts before mentioned; and of this sort, is the Iron made with Pit-cole, Sea-cole for the most part, and therefore more sufficiently to be preferred.

2. More cheaper Iron there cannot be made, for the Author did sell pigg or cast Iron made with Pit-cole at four pounds per Tun, many Tuns in the twentieth year of King James, with good profit; of late, Charcole Pig-iron hath been sold at six pounds per Tun, yea at seven pounds per Tun hath much been sold.

Also the Author did sell Bar-iron Good and Merchantable, at twelve pounds per Tun, and under, but since Bar-iron hath been sold for the most part ever since at 15*l.* 16*l.* 17*l.* and 18*l.* per Tun, by Charcole Iron-Masters.

3. More Excellent for diverse Reasons, and principally, being the meanes whereby the Wood and Timber of this Island almost

exhausted, may be timely preserved yet, and vegetate and grow again unto his former wonted cheapness, for the maintenance of Navigation, which is the greatest Strength of Great Brittain, whose Defence and Offence for all the Territories that belong unto it, next under God and his Vice-Gerent, our Sacred Majesties Cares, consists most of Shiping, Men of War, Experienced Mariners, Ordnances, Ammunition, and Stores, the Ordnance made therewith will be more gray and tough, therefore more serviceable at Sea and Land, and the Bar-iron will wall, rivet, and hold better then most commonly Charcole Iron.

2. More Excellent, not onely in respect the Invention of making of Iron with Pit-cole and Sea-cole will preserve Wood and Timber of Great Brittain so greatly consumed by Iron-Works of late.

But also in respect, this my Invention will preserve many Millions of Tuns of Small-cole in Great Brittain, which will be lost in time to come, as formerly they were, for within ten miles of Dudley Castle, is annually consumed four or five thousand Tuns at least of small Pit-cole, and have been so consumed time out of mind under ground, fit to have it made Pit-iron with; which coles are and (unless Iron be made therewith) will be for ever totally and annually lost; if four or five thousand Tun of Cole be consumed within ten miles compass, what Coles is thus consumed in all England, Scotland, and Wales! which is no good Husbandry for Great Brittain, hinc ille lacrime, that our Timber is exhausted.

Must I be still opposed, and never enjoy my Inventions, nor Great Brittain the Benefit?

Must my Pattent be obstructed in Peace, as it was extinct by the Wars?

And must not my Pattent be Revived for the making of Iron with Pit-cole, Sea-cole, Peat, and Turf, but find Enemies still to oppose it?

How many thousand Tuns of Iron might have been made but since my first Invention, An. Jacob. 18th by my means with Pit-cole, and Sea-cole (lost) if I had not had Enemies; and had not wood and timber been preserved?

But most men will aver, that it doth concern the Author to Demonstrate the great losse mentioned formerly of Pit-cole annually;

It is thus,

There is at least within ten miles of the Castle of Dudley, twelve or fourteen Cole-Works, some in Worcester, and some of them in Staffordshire (now in work, and twice as many in that Circute not in work) each of which Works get two thousand Tun of Cole yearly, some get three, four or five thousand Tun of Coles yearly: and the uppermost or top measures of Coles are ten, eleven, and some twelve yards thick; the Coles Ascending, Basseting, or as the Colliers term it, Cropping up even unto the superfices of the Earth, and there the Colliers formerly got the Coles; but where the Coles is deep and but little Earth upon the measures of Coles, there the Colliers rid off the Earth, and dig the Coles under their feet; these Works are called Foot-rids.

But of these Works there are now but few, some of these small Coles in these open Works, the poor people did carry away, but paid nothing for them in former times, termed the Brain Carriages.

But now the Colliers working more in the deep of these Works, they are constrained to sink Pits some of which Pits are from eight unto twenty yards deep, and some are near twenty fathome deep, which fathome contains two yards.

In these Pits, after you have made or hit the uppermost measures of Cole, and sink or digged thorow them, the Colliers getting the nethermost part of the Coles first, about two yards in height or more, and when they have wrought the Crutes or Staules, (as some Colliers call them) as broad and as far in under the ground, as they think fit, they throw the small Coles (fit to make Iron) out of their way on heaps to raise them up so high, to stand upon, that they may, with the working of their Picks or Maundrills over their heads, and at the one end of the Coles so far in as their Tool will permit, and so high as their working cometh unto a parting in the measure of Cole, the which Coles, to the parting by his self clogging and ponderous weight, fall often many Tuns of coles, many yards high down at once; with which fall and the Colliers breaking of the said Cole, many small coles do so abound of no use, and fit for no sale; that in getting of twenty thousand Tun of Pit-cole, one half near is small cole, not drawn out of the Pits, but destroyed, left, and lost; which small cole, with the sleck thrown moyst together, (heat the sooner) and by means of its sulphurousness fire in the Pits, to no small prejudice unto the Owners of the Works, and the Work-

men, besides Great Brittains Loss; which Cole might have made many thousand Tuns of Iron, and also have preserved this Islands Woods and Timber; I might here give you the names, and partly the nature of every measure, or parting of each cole lying upon each other; the three uppermost measures are called the white measures for his white Arcenical, Salsuginos and Sulphurious substance which is in that Cole; the next measure, is the shoulder-cole, the toe-cole, the foot-cole, the yard-cole, the slipper-cole, the sawyer-cole, and the frisly-cole, these last three coles are the best for the making of Iron, yet other coles may be made use of.

I might give you other names of coles, but desire not prolixity, yet must I tell you of a supernumary number of Smiths within ten miles of these Cole-Works near twenty thousand; yet God of his Infinite goodness (if we will but take notice of his goodness unto this Nation) hath made this Country a very Granary for the supplying these Men with Iron, Cole, and Lime made with cole, which hath much supplyed these men with Corn also of late, and from these men, a great part not only of this Island, but also of his Majesties other Kingdomes and Territories with Iron wares have their supply, and wood in these parts almost exhausted, although it were of late a mighty wood-land Country.

Now if the Coles and Iron-stone so abounding were made right use of, we need not want Iron as we do; for very many measures of iron-stone are placed together under the great ten yards thickness of cole, and upon another thickness of coles two yards thick, not yet mentioned, called the bottom-cole, or the heathen cole, as if God had decreed the time when, and how these Smiths should be supplyed, and this Island also with Iron, and most especially, that this cole and iron-stone, should give the first, and just occasion for the invention of the making of iron with pit-cole, no place being so fit for the invention to be perfected in, then this Country, for the general good; whose Woods did formerly abound in Forrests, Chases, Parks and Woods, but exhausted in these parts.

Now for the names of the iron-stone, the first measure is called the Black-row-graines, lying in very hard and black Earth.

The second measure is the Dun-row-graines, lying in dun earth or clay.

The third measure is called the white row grains, lying in very white Earth or Clay; under these three measure are sundry other

measures, and are called, first, the Rider Stone; secondly, the Cloud Stone; thirdly, the bottom Stone; fourthly, the Cannock or Cannotstone, which last may wel be so caled (although all the other measures be very good) yet this Stone is so Sulphurious and Terrestrial, not fit to make Iron; because the Iron thereof made is very Redshare, which is that if a workman should Draw or Forge out a Share mould fit for a Plough in that red heat, it would crack and not be fit for the Use of the Husbandmans Plough or Share. I may take occasion here to speak of the Nature of Coldshare Iron, which is so brittle if made of the grain Oare or Iron stone would be almost as brittle as some Regulus Antimonii made Iron, for with one small blow over an Anvil you may break the biggest Bar that is, if it be perfect coldshare Iron; nay the Plough-man often breaks his Share point off if it be made of coldshare Iron. But perfect tough malliable Iron will not break feisibly in hot-heat or cold, as coldshare wil, or red hot as Sulphurious veneriated redshare Iron will; but yet tough enough when it is cold: All which aforesaid qualities of Iron the Authour very well knoweth how to mend their Natures, by finning or setting the finery, lesse transhaw more borrow which are terms of art, and by altering and pitching the works, and plates, the fore spirit-plat, the tuiron, bottome, back and breast or fore-plate, by the altering of which much may be done, if the work be set transhaw and transiring from the blast, the Iron is more coldshare lesse Fined, more to the Masters profit; lesse profitable to him that makes it into manufactorage, and lesse profitable to him that useth it; but the Iron made in a Burrow work, becometh more tough and serviceable; yet the nature of all Iron stone, is to be considered, both in the Furnace, and in the finery, that the Sulphurious Arceniall and Veneriating qualities, which are oftentimes in Ironstone be made to separate, in both the works from the fixed and fixing bodies of Iron, whose fiery quality is such, that he will sooner self calfine than separate from any Sulphurious veneriated quality.

No man, I hope, need to be offended at any terms of Art, it hath been alwayes lawfull for Authours of new Arts and Inventions, at their own pleasures, to give name to their new Inventions and Arts, every Tradesman is allowed it in his mystery.

But the Authour hath as much as he could avoided the terms of Art that Simon Sturtenante and others have used, which are very

many: onely the Author hath given you the common names and terms (for the most part) which are so common among Forge-men and Founders, as is nothing more common; but kept secret amongst them and a mystery not yet known, but unto very few Owners of Iron-works; nay I have not yet troubled your memory with any of the Founder terms, of but making his harth as the Timpe stones, the Wind-wall stones, the Furion stones, the Botton-stone, the Back-stones and the Boshes, in the making and pitching of which harth, is much of the Mystery.

I must confesse, there is given unto some Phylosophers, etc filii Artis, some few terms how the Sulphurious Arsenicall, Bituminos, Antimoniall, Venerial, and other poysonous qualities, either in the Pit-cole, Sea-cole, or the Iron-stone, may be in part at the Furnace separated, and not be permitted to incorporate in the Iron, and if it be incorporated, yet by Fining at the Forge, to fetch it out; also to melt extract, refine, and reduce all mines mettals and minerals, unto their species with Pit-cole, Sea-cole, Peat, and Turff, by wayes not yet in use, which the Authour will make known, hereafter, if God permit him health, time and space, or leave his knowledg unto his Brother Aylmore Folliott, Esq; his Nephew Parks-house, Esq; and to his Kinsman Master Francis Dingley, to declare unto this latter Age of the World, in which God is pleased to manifest many of his Secrets; Qui vult secreta scire, secreta secrete sciat custodire.

Having suffered much, ever since the Year 1618. unto this present for the general good, as by the preceding discourse appears for the making of Iron with Pitcole, Seacole, Peat, and Turff; for the preservation of Wood & Timber of Great Brittain so much exhausted, for the future prevention of which,

Is first, to permit the Authour to enjoy His Pattent, and fully to perfect his said Inventions (obstructed in the Reign both of King James and in the Reign of his Sacred Majesty King Charls the First, of ever Blessed Memory; and lately since his most Sacred Majesties happy Restauration) who desires nothing but to be animated with the Patent revived according unto the Statute of 21. Iacob. for Inventors.

Secondly, to impower the Authour or any other Agents to take care that no Pit-cole, or Seacole be any wayes wilfully destroyed under ground.

Thirdly, To put all former good Laws in Execution, and to make

others for the preservation of Wood and Timber of these Nations, especially neer Navigagable River or Seas.

Fourthly, Seeing there goeth out of England, Scotland and Wales, many thousand Tons Annually of Pitcole and Seacoles to furnish France, and also the Smiths thereof Spaine, Portugal and Flanders, and especially the Smiths thereof; the Low-Countries and the Smiths thereof, besides the Hollanders carries great quanties of our Coles unto Foreigne parts, without which those Countries cannot subsist: Now the Authors desire is, that where there is a conveniency of Iron stone or Ewre, the Coles may not be transported (paying His Sacred Majesties Duty) untill Order from His Majesty or his Privy Council.

Fifthly, That no Pitcole be Exported, seeing that Wood fuell and Timber is decayed for Buildings, and instead thereof Brickmaking (formerly spending Wood, but now coles) is much in use; also is Glasse now made with cole, but formerly were there many Thousand Loads of Wood fuell spent in the making thereof, and the Glass Invention with Pitcole was first effected near the Authours Dwelling.

Sixthly, Making of Steel, Brewings, making of Coppras, Allum, Salt, casting of Brasse and Copper, Dyings, and many other Works were not many years since done altogether with the Fuell of Wood and Charcole; instead whereof, Pitcole, and Seacole is now used as Effectually, and to a far better Use and Purpose; besides the preservation of Wood and Timber.

Seventhly, That which is somewhat neerer the mark and Invention; the Blacksmith forged all his Iron with Charcole, and in some places where they are cheap, they continue this course still, but small Pitcole and Seacole, and also Peat and Turff hath and doth serve the turn as well and sufficiently as Charcole.

Eighthly, That which is nearest, and my perfect Invention, and neer the Authours Dwelling, called Greens-lodge, there are four Forges, namely, Greens-forge, Swin-forge, Heath-forge and Cradley-forge.

Which Four Forges have Barred all or most part of their Iron with Pitcole ever since the Authours first Invention, 1618. which hath preserved much Wood: In these Four, besides many other Forges do the like; yet the Authour hath had no benefit thereby to this present.

Yet by this Barring of Iron with Pit-cole 30000 loads of Wood

and more have been preserved for the general good, which otherwayes must have been had and consumed.

Symon Sturtevant, in his Metallica, in the Epistle to the Reader, saith, That there was then Anno 12. Jacobi in England, Scotland, Ireland and Wales 800 Furnaces Forges, or Iron Mills making Iron with Charcole: Now we may suppose at least 300 of these to be Furnaces, and 500 to be Forges; and each Furnace making fifteen Tun per Week of Pig or cast Iron, and work or blow but Forty week per Annum, but some Furnaces make Twenty Tuns of Pig Iron per Week, and two Loads of Charcole or there about, go to the making of a Tun of Pig Iron: And two Loads (or two cords) of Wood at the least, go to the making of a Load of Charcole.

Now what Loads of Wood or Charcole is spent in great Brittain and Ireland Annually? but in one Furnace, that makes Fifteen Tun per Week of Pig-Iron for Forty weeks: I shall give you the Table, and leave you to judge of the rest of the Furnaces.

	Charcole,	Wood,
15. Tun per week spends of	30 loads	60 loads.
Per Annum 40 weeks spends	1200	2400 loads.

Also for one Forge that make Three Tuns of Bar Iron weekly for Fifty weeks, but some Forges make double my Proportion, and spend to Fine and Bar out each Tun three Loads of Coles: To each Tun.

3 Tun per week	Charcole	Wood
	9 Loads	18 loads
Per Annum	450 loads	900 loads

By these Examples, may you see, the vast quantities of Charcole, or Wood, that the 300 Furnacis spend weekly, or yearly, and the 500. Forges workings all the year, spend little lesse then the Furnaces: It being impossible, after this rate for Great Brittain or Ireland, to supply these her works with Charcole in Fining of Iron at the Fineries, yet the Forges that need but half the Charcole may be permitted to use Charcole, and may be supplyed with under Woods.

Let us but look back unto the making of Iron, by our Ancestors, in foot blasts, or bloomenies, that was by men treading of the Bellows, by which way they could make but one little lump or bloom of Iron in a day, not 100 weight, and that not fusible, nor fined, or malliable, untill it were long burned and wrought under

Hammers, and whose first slag, sinder or scorius, doth contain in it as much, or more Iron, then in that day the workman or bloomer got out, which Slag, Scorius, or Sinder is by our Founders at Furnaces wrought again, and found to contain much Yron and easier of Fusion than any Yron stone or Mine of Yron whatsoever of which slag and Sinders, there is in many Countryes Millions of Tuns and Oaks growing upon them, very old and rotten.

The next invention was to set up the Bloomeries that went by water, for the ease of the men treading the bellows, which being bigger, and the waterwheel causing a greater blast, did not onely make a greater quantity of iron, but also extracted more iron out of the slag or sinder, and left them more poorer of iron then the foot-blasts, so that the Founders cannot melt them again, as they do the foot blast sinders to profit: Yet these Bloomeries by water (not altogether out of use) do make in one day but two hundred pound weight of iron, or there abouts neither is it fusible, or malliable, but is unfined untill it be much burned, and wrought a second time in fire.

But some of the now going Furnaces with Charcole, do make two or three Tun of Pigg or cast iron in 24 hours.

Therefore I do not wholly compute the vast quantities of charcoles and wood spent in these voragious works, which quantity of cast iron, with pit-cole and Sea-cole, at one Furnace I desire not, but am contented with half the proportion, which once I attained unto before my Bellows were riotously cut, that is one Tun in 24 hours; we need not a greater quantity, if the like quantity were made in Furnaces in Scotland, and Wales, which abounds with Pit-cole and Sea-cole, as well as England; and our supernumery Smiths, Founders, and Forgemen, and other Tradesmen might be there imployed, thereby to furnish His Majesties Plantations, as well, if not better then England, where Coles are far cheaper then in England.

Although vast quantities of Coles do abound near the Authors dwelling, yet twenty thousand Smiths or Naylors at the least dwelling near these parts, and taking of Prentices, have made their Trade so bad, that many of them are ready to starve and steal; so that it is wished there were some courses taken to mend their Trade, imploy them in other parts, or permit them, not to take so many Prentices, all which have great occasions to use Pit-cole, and

had not these parts abounded with cole, it would have been a great deal worse with them then it is; but of the cole there is, nor will be any want, nor of iron-stone.

The manner of the cole-veins, or measures in these parts, and also of the measures of iron-stone, or mines, how they lye, be, or increase, some veins lye circuler, some sami-circuler, some ovall, some works almost in a direct line, and some works parts of a Circle; as by the Circle, it being onely for a small Example to judge the rest of the Mines by may appear.

WRIGHTSON'S PATENT HYDRAULIC APPARATUS FOR LOWERING CHARGES INTO BLAST FURNACES.

THE objects of this invention are:—

1st. To do away with the laborious effort expended in the ordinary way of lowering and raising by a winch, substituting for this the simple opening of a valve.

2nd. The reducing of the time, during which the bell is open, to a minimum, so that the least possible amount of gas shall be wasted.

3rd. The possession of a means by which, in case a lump of material should stick between the bell and hopper, the former can be immediately lowered until the lump is liberated.

The bell is worked by an ordinary beam with a balance weight at the opposite end, which always keeps the bell close until the charge is liberated.

Referring to the drawing, a connecting rod (*a*) attaches the balance-weight end of the beam to the piston of a small oscillating cylinder (*b*) filled with water or oil. Connecting the top and bottom of this cylinder is an external passage (*c*) in which is placed a brass valve (*d*), which, being more or less opened, regulates to a nicety the speed of the piston in rising or falling.

When it is desired to lower the charge, the screw-catch (*e*) is relieved by a quarter turn of a handle, and the valve (*d*) is opened. As the bell descends the piston rises, the water at the top of the piston passing through the passage and valve (*d*) to the under side of

the piston. As soon as the bell is relieved of its charge, the piston descends again, and the bell closes, the whole operation being completed in a few seconds.

In case of a large lump sticking between the bell and hopper ring, which is an occasional occurrence in charging, a small hand-pump(*f*) is fitted at the side of the cylinder, which can be made, when required, to force the water from the top to the bottom, thus raising the piston and lowering the bell until the lump sticking is disengaged.

The same water is used over again, and a constant supply is, therefore, not required.

The relieving of the catch, and the opening of the valve, being operations of a very simple and easy character, it is found that the men much prefer the hydraulic arrangement to any other; hence its rapid adoption.

The great waste of gas, which takes place in the opening of a bell by the ordinary arrangement, has led several ironmasters to attempt the construction of specially-made bells for catching the gas which would otherwise escape. The complication of any arrangement of this kind is best avoided if the ordinary bell can be opened and shut with such quickness that the charge has just time to fall from the bell. The hydraulic brake is well adapted for this, as the opening of the valve to its full area allows the charge at once to descend. The change of motion of the water through the valve allows the bell to hang open for a second or two, while the charge clears itself, after which it at once closes by the action of the balance weight, the passage of the water through the valve being so controlled that there is no shock at the closing of the bell. The time in practical working during which the bell is open, *i.e.*, the time from which it leaves its seat until it returns again, is from 6 to 8 seconds, which is considerably less than the time occupied by the ordinary winch arrangement. As every unnecessary second that the bell is open represents a large amount of fuel lost, it is evidently desirable to limit this time to the shortest period.

The small pump at the side for lowering the bell in case of a lump sticking, is found to be very useful at times, and a few rapid strokes of this pump will very quickly relieve the obstruction.

The cylinder cover is formed into a small tank, which supplies any loss which may occur through leakage. This may be replenished once a month.

The safety of the apparatus is a recommendation, as on account of all the motions being very steady, and controlled by the water in the cylinder, jerks and undue strains are avoided.

The arrangement has been adopted in many of the largest modern furnaces in the North of England, and is now applied to a total of 42 furnaces.

Messrs. Head, Wrightson, & Co., Stockton-on-Tees, are the sole makers of the apparatus.

ON THE GASES EVOLVED FROM PIG IRON, STEEL AND WROUGHT IRON, AND COKE, ON HEATING IN VACUO, AND ON THE ESTIMATION OF CARBON IN THE SAME.

By MR. JOHN PARRY, Ebbw Vale Iron Works, Newport, Mon.

In the *Chemical Journal* (vol. v., 1867) Professor Graham first published his remarkable experiments, showing that many of the metals were capable of taking up several times their own volume of gas, and evolving the same on heating in *vacuo*, using that invaluable instrument designed by Dr. Hermann Sprengel, now known as the Sprengel Mercurial Air Pump. This instrument affording a ready means of, first, creating a vacuum, and afterwards collecting the gases evolved on heating the metal contained in a close tube, it was also shown that many of the metals contained what may be termed natural gas, *i.e.*, gas occluded in the metal during its manufacture, and ever afterwards retained under ordinary conditions.

The author was much struck by these experiments, notably those on the gases evolved from wrought iron. It was shown by Graham that on heating carefully cleaned wrought iron wire in *vacuo*, 46 grms. of Sp. Gr. 7·800 gave, in two hours, 46·85 c.c. gas measured at 15″C, or that 1 vol. iron had discharged 7·94 vol. gas, of which about $\frac{2}{3}$ was carbonic oxide.

Another sample gave 7·27 vol. gas, which contained about 15 per cent. carbonic acid, the remainder was principally carbonic oxide, with hydrogen and a trace of hydro carbon. A sample of exhausted

iron wire was exposed at a red heat to the action of carbonic oxide, and was found to have taken up 4·15 times its own vol. of carbonic oxide.

Professor Graham remarks, the relations of the metal iron to carbonic oxide appear to be altogether peculiar. The intervention of carbonic oxide in the process of cementation with charcoal has long been recognised. The decomposing action of carbonic oxide has been supposed to be exercised only at the external surface of the metal. The experiments appear to show that the process is not confined to the surface of the iron bar, but may occur throughout the substance of the metal, in consequence of the prior penetration of the metal by carbonic oxide, and it would appear that the diffused action of carbonic oxide is the proper means of distributing the carbon throughout the mass of iron. It is also suggested that cementation may be promoted by alternately heating and cooling the bar iron. Also, the lowest red heat appears to be most favourable for the absorption of carbonic oxide by iron. Some time ago, the author made some experiments in this direction, by forcing carbonic oxide into an air-tight vessel containing a bar of red hot iron. It was not proved that the bar had absorbed CO, but in all cases the pressure of the gas, shown by a gauge, first rapidly, and then slowly, diminished, until, after many hours, only atmospheric pressure was shown.

It was conceived that a more extensive series of experiments in this direction, on the various kinds of pig iron, steel, and wrought iron, manufactured at the works, might lead to useful results; at any rate, as Graham had proved the existence of these gases in iron, it was desirable to determine the amount and kind of gas or gases occluded in pig iron, &c., such information being rendered more valuable from the fact that the history of the manufacture of each sample tested could be readily obtained. It was, however, found that these experiments presented grave difficulties, and much time was lost ere reliable results could be obtained, and even up to the present, the author can only lay before the Institute a few experiments at the low temperature, necessitated by the use of glass tubes, failing to get any other kind of tube capable of retaining a good vacuum for many hours. These difficulties have, however, been overcome, and it is hoped that soon a complete series of experiments will be ready, giving the absolute amount and kind

of gas or gases contained in pig iron and steel of various qualities; also, special determinations of the gas contained in overheated steel and wrought iron.

Part I.—Gases occluded in Pig Iron, Wrought Iron, and Steel.

These are all qualitative experiments; the absolute amount of gas given off from a given weight of iron has not yet been determined.

Expt. 1. 50 grms. spiegeleisen heated in *vacuo* at a low red heat for 3 hours, collected 12 c.c. gas; barometer 760 millimetres; temperature 15 degs. centigrade; containing per cent.—

CO_2.	CO.	Oxygen.	Hydrogen.
0·942	17·87	0·000	81·105

2. 50 grms. common white pig iron, heated as above $6\frac{1}{2}$ hours, collected 13 c.c. gas, containing per cent.—

CO_2.	CO.	Hydrogen.	N.
6·800	2·32	84·00	6·88

3. 37 grms. good wrought iron, heated 2 hours, gave 9·4 c.c. gas, containing per cent.—

CO_2.	CO.	H.	N.
9·920	34·262	54·100	1·718

4. 4·75 grms. grey pig iron, heated 2 hours, gave 15·81 c.c. gas, containing per cent.—

CO_2.	CO.	H.	N.
1·600	5·200	89·700	3·250

1	cubic	inch	spiegeleisen	discharged	about	2	cubic inches gas.
1	„	„	white pig iron	„	„	2	„ „
1	„	„	wrought iron	„	„	2	„ „
1	„	„	grey pig iron	„	„	2·1	„ „
1	„	„	steel	„	„	·13	„ „

5. 10 grms. soft steel, heated 2 hours, gave 18·4 c.c. gas, containing per cent.—

CO_2.	CO.	H.	N.
16·550	24·352	52·610	6·488

It is noticeable that grey iron contains the largest quantity of hydrogen, the experiments showing that it is gradually eliminated in the process of manufacture from raw pig to wrought iron.

The grey iron and steel were exposed to a higher temperature than the other samples, as follows:—

A clean porcelain tube containing the metal was enclosed in a

tube of infusible glass closed at the end; a clay tube was moulded around these; the lower part containing the iron was placed in a clay crucible, the latter was then filled with blast furnace slag.

The anterior end of the tube was drawn out and connected with the pump in the usual manner, and a good vacuum having been first formed in the cold, the crucible, &c., was strongly heated in a small charcoal furnace and the molten slag covering and enclosing the whole, it was found that a good heat could be applied without danger from leakage or fusion of the tubes.

The grey pig iron gave off much more gas than was expected; the experiment, however, was perfect throughout, and every precaution taken, the tubes being clean and perfectly dry.

The gas, in this instance, may be occluded in the graphite; to test this the author intends separating the latter according to Snelus's method, and testing the portion containing the excess of graphite in *vacuo.*

Clean lumps of grey pig iron were used for the steel, the sample was drilled in the laboratory with new drills, never before used, and perfectly free from grease or oil. Not the slightest alteration was noticed in the quality of the wrought iron. It behaved exactly like the companion piece cut off the same rod, worked and bent by the smith.

Part II.—On the Gases contained in Coke, evolved in vacuo; Application of the Sprengel or Mercury Air-pump.

It has always been a doubtful question with most chemists and metallurgists whether coal could be completely deprived by heat of its volatile constituents. The usual rule has been to expose the coal in a closed crucible to the heat of a gas or spirit blow-pipe, and to assume the residue (after it had ceased to lose weight) to contain only carbon, and incombustible matter or ash.

Nevertheless, Dr. Percy and others have called attention to the fact that coke from the hardest burnt coals, on being subjected to elementary analysis, showed a loss of carbon. This loss might have been due to errors of analysis, but it was so constant that it has been generally assumed it is due to the presence of gaseous matter, by inference oxygen and nitrogen.

The author has, however, found that, contrary to the general opinion, coal persistently retains hydrogen, and even at the highest

heat at his command (a Sefstrom's furnace) he has failed to entirely free coal from volatile matter; also that all kinds cannot be deprived of their volatile constituents with equal facility by merely heating in a closed crucible.

The writer's attention was more particularly directed to this from the fact that he found great difficulty in freeing a sample of coal (sent to him for examination) from volatile matter. The coal was analysed with the following results:—

No. 1. Coal.

Elementary Analysis.

Carbon.	Hydrogen.	Sulphur.	Ash.	Oxygen and Nitrogen.
65·600	4·243	0·807	5·170	24·180

Proximate Analysis.

Gas Coke.	Tar.	Water.	Illuminating Gas.
82·69	4·67	3·00	9·64

On heating 100 of this coal in a closed crucible at a heat which, from experience extending over many years, had always been found sufficient and to agree closely with results on the large scale* at the works, it gave 77·28 of coke; this not agreeing with the elementary analysis, several combustions were made, with results agreeing closely. It was therefore inferred the coke still contained volatile matter.

800 grms. of the gas coke was now heated to full redness in a small iron retort. Gas burning with a pale blue flame was rapidly given off for the first hour, then very slowly, and ceased in 30 minutes; total time 1½ hours. Coke in retort weighed 759 grms. =5·2 per cent. loss.

100 grms. coke from retort heated in close platinum crucible (Griffin's gas furnace and large burner used) lost:—1·15 hours, 1·9; 3½ hours, 9·8; 1·40 hours, 12·9. Total loss, heated 6·25 hours =12·9 per cent.

20 grms. of the coal over large burner as above heated 4½ hours weighed 14·3; again 1·35 hours, 13·6; again 1·40, 12·8=coke, 64·00; loss, 36·00.

Analysis of Gas Coke.

Carbon.	Hydrogen.	Sulphur.	Ash.	Oxygen and Nitrogen.
84·360	0·187	0·850	8·300	6·303

* Another chemist of considerable experience also gave 77 coke, unknown to the writer, and before he had commenced these experiments.

Analysis of Coke heated 7·55 hours.

Carbon.	Hydrogen.	Sulphur.	Ash.	O and N by diff.
89·450	trace	0·795	8·450	1·305

In order to further test the gas coke, 20 grms. were heated in a Sefstrom's furnace for 3 hours; lost 3·6 grms.=18·6 per cent. loss.

20 grms. of the above heated coke heated in *vacuo* under the Sprengel pump for 2½ hours gave 7·664 centims. of gas, containing per cent.—

Carbonic Acid.	Carbonic Oxide.	Hydrogen.	Nitrogen by diff.
75·77	5·60	18·13	0·50

Volume of coke (measured), 15·4 c.c.

It now occurred to the author that it would be interesting to subject the gas coke to heat under the Sprengel pump, collecting and testing the evolved gases from time to time. 20 grms. used and heated 2½ hours gave 301·5 c.c. gas, containing—

Carbonic Acid.	Oxygen.	Carbonic Oxide.	Hydrogen.	Marsh Gas.	Nitrogen.
22·80	0·00	13·49	50·00	13·80	0·00

Also water and tarry matter.

Again heated 7 hours, 586 c.c. gas, containing—

CO_2.	CO.	Hydrogen.	Marsh Gas.	N.
3·10	3·30	93·45	0·00	0·00

Again heated 1½ hours, 65·6 c.c. gas containing—

CO_2.	CO.	H.
5·721	5·150	89·129 by diff.

Again heated 1½ hours, 80·00 c.c. gas containing—

CO_2.	CO.	H.
4·800	5·110	90·090 by diff.

Again heated 1 hour, 62·5 c.c. gas containing—

CO_2.	CO.	H.
9·65	0·70	89·65

Again heated 1 hour, 21·6 c.c. gas, containing—

CO_2	Oxygen.	CO.	H.	N.
9·385	0·00	8·200	81·200	1·215

Total, 1117·2 c.c. gas from coke heated 14½ hours in glass tube in gas flame=about 72·5 volumes of coke used.

All the gas was not extracted, but in attempting to cool down the tube for next class experiments, it cracked, and consequently spoilt the experiment. Taking, however, the previous trial of the coke heated in Sefstrom's furnace, it is pretty evident hydrogen is eliminated, leaving principally only carbonic acid.

A sample of a different vein of coal was now taken and examined.

No. II. Coal.

Elementary Analysis.

Carbon.	Hydrogen.	Sulphur.	Ash.	O and N by diff.	Coke.
73·688	4·956	1·826	7·300	12·23	63·50 p.c.

20 grms. of the coke under Sprengel pump—

		Gas. c.c.	Carbonic Acid.	Oxygen.	Carbonic Oxide.	Cyanogen.	Hydrogen.	Nitrogen.
No. 1.	Heated 2 hours	28	77·12	trace	4·153	0·00	0·000	17·780
	Again $2\frac{1}{2}$,,	32	33·22	0·00	0·000	0·00	34·561	31·000
	$4\frac{1}{2}$,,	60						

20 grms. of coal again coked 4 hrs. 20 mins. in Sefstrom's furnace, gave only 62·2 per cent. coke (under Sprengel pump)—

		Gas. c.c.	Carbonic Acid.	Oxygen.	Carbonic Oxide.	Cyanogen.	Hydrogen.	Nitrogen.
No. 2.	Heated 1 hour	32·5	67·419	0·00	12·420	0·00	5·325	14·020
	Again 3 ,,	26·6	61·449	0·00	10·427	0·00	24·564	3·484
	4 ,,	59·1						

Vol. of coke, 20 grms. = 16 c.c. = about 3·75 vols. of gas to 1 vol. of coke. Coke made from the above coal at the works, thoroughly coked sample taken, dried at a dull red heat, lost 0·933 per cent.

Dried coke under Sprengel pump 2 hours gave 51·5 c.c. gas containing—

Carbonic Acid.	Carbonic Oxide.	H. and N.
91·400	3·583	5·017

Nos. 1 and 2 analyses differ, but the experiments were carefully made.

The coke from this coal differs from No. 1 in containing nitrogen, which appears to have been eliminated from No. 1 in previous coking. It is in good repute for iron smelting; No. 1 is never used, having been found unfit for use in the blast furnace.

Other samples of coke were now taken from the works and tested under the Sprengel pump, with the following results:—

Hard, well burnt coke; 20 grms., 2 hours under Sprengel pump, gave 79·2 c.c. gas, containing, per cent.—

Carbonic Acid.	Carbonic Oxide.	Hydrogen.	Nitrogen.
85·720	8·590	5·680	0·000

Hard coke, mixed coals; 20 grms., 2 hours under Sprengel pump, gave 42·4 c.c. gas, containing, per cent.—

Carbonic Acid.	Carbonic Oxide.	H and N. (Both present; H shown by explosion, but not separated)
57·413	28·562	14·025

Analysis of Coke.

Ash.	Sulphur.	Loss at Red Heat.	Loss under Sprengel pump.	Carbon by diff.
12·100	1·400	1·500	0·586	84·414

Common coke exposed in open air for some time, badly coked sample; 20 grms., 2 hours under Sprengel pump, gave 91·7 c.c. gas, containing—

Carbonic Acid.	Carbonic Oxide.	Hydrogen.	Marsh Gas.	Nitrogen.
39·020	7·673	53·317	trace	0·000

Analysis of Coke.

Ash.	Sulphur.	Loss at Red Heat.	Loss under Sprengel pump.	Carbon. by diff.
14·000	1·370	4·820	1·000	78·810

The author thinks it premature to hazard any suggestions as to the effect of the gases shown to be contained in coke when used in the blast furnace. It is, however, probable that they are only eliminated at a very high heat, and most probably the carbonic acid is retained up to the fusing point of cast iron. He has, however, noticed that what is termed weak coke always contains the largest proportion of hydrogen, and that nitrogen is absent or only present in small quantities.

Part III.—Estimation of Carbon in Pig Iron, Wrought Iron, and Steel, by combustion with oxide of copper in vacuo under Sprengel Pump.

In the course of the previous experiments with the view of estimating the amount and kind of gas occluded in pig iron, &c., it was thought necessary to heat iron with oxide of copper *in vacuo*, and, ultimately, it was found that accurate carbon determinations could be made as follows:—

(1). Digesting the metal in solution of $CuSO_4$, filtering and washing residue of precipitated copper mixed with the carbon through asbestos.

(2). The dried residue mixed with about 50 grms. pure oxide of copper, and placed in a combustion-tube sealed at one end and drawn out at the other, the drawn-out end being fitted into a water-joint connected with the pump, as shown in Frankland and Armstrong's Memoir, (*Chemical Journal*, vol. vi., p. 90). A vacuum being first formed, the tube was heated to a red-heat until gas ceased to be evolved. The gas was collected in a carefully-calibrated gas-tube, and measured with the usual corrections for

temperature, pressure, and moisture, the amount of carbon being calculated from the number of c.c., measured according to Bunsen. Several trials were made with iron direct mixed with CuO, but all failed to give the full amount of carbon.

A sample, ascertained to contain 3·2 per cent. carbon, kept heated under the pump for more than 12 hours, gave only 2·97 carbon, with CO_2 gas still being evolved. Other trials—heat kept on from 2 to 4 hours—gave 2 to $2\frac{1}{2}$ per cent. carbon.

It was found, in all cases, that the gas given off *in vacuo* consisted entirely of pure CO_2, but that care was necessary to insure the perfect purity of the CuO used and freedom from dust.

Expt. 1. Grey pig iron, $\frac{1}{2}$ grm., heated 1 hour under pump, gave 29·9 c.c. CO_2=carbon 3·206 per cent.; ditto, by ordinary combustion with CuO in current of O, carbon (1) 3·280, (2) 3·264. To experimentally test the calibration of the gas-tube, a light glass flask, about 100 c.c. capacity, was fitted with a capillary tube and glass stopcock. This was connected with the pump, and the air having been exhausted, the stopcock was closed, the apparatus detached from the pump, and weighed. By passing the capillary tube up the tube containing the gas, and opening the stopcock, the CO_2 gas was drawn into the flask.

First weight exhausted flask ...	23·274	grms.
Second weight with CO_2 drawn in	23·333	„
	CO_2 0·059	

Carbon 3·206 per cent.

Expt. 2. Another sample grey pig iron. (1). Ordinary combustion, carbon 3·600 per cent. (2). Under pump, gas pumped direct into weighed KO bulbs, carbon 3·654 per cent.

Expt. 3. It being thought probable that by ordinary combustion CO_2 might be retained in the oxide of copper, 1 grm. of a grey pig iron was treated with solution of $CuSO_4$, washed, &c., mixed with CuO, and placed in a combustion tube, drawn out so as to admit of detaching the O-generating apparatus, and, readily sealing the end in the blowpipe flame, gave carbon 3·228 per cent. The O apparatus was detached, the tube sealed up and allowed to cool; when cold the tube was attached to the pump, exhausted, and again heated. A considerable quantity of gas was given off,

which was found to be pure O, without the slightest traces of CO_2 and CO.

Expt. 4. Puddle bar, described as being thoroughly puddled iron. Ordinary combustion, carbon (1) 0·143 per cent. (2) 0·131 per cent. Combustion in *vacuo*, carbon 0·1465 per cent.

Expt. 5. Wrought iron armour plate. Combustion in *vacuo*, carbon 0·1426 per cent.

Expt. 6. Steel. Combustion in *vacuo*, carbon 0·2972 per cent. Eggertz's colour test, carbon 0·2800 per cent.

It appears, therefore, that the ordinary combustion method with CuO in O gas gives fairly accurate results. The author is, however, of opinion that more *sure* results* may be obtained by the use of the Sprengel pump; and although the method appears more tedious, and requires some manipulative skill, yet, if the pump be properly fitted up and the gas tubes carefully calibrated, combustions may be made with great facility.

Ordinary combustions require the undivided attention of the operator, and from the number of parts, considerable care in guarding against leakage; moreover, the KO bulbs present a considerable surface for the deposit of dust and moisture.

With the pump, the vacuum once being secured and preserved to the end of the combustion, there is no fear of error from leakage, and the operator—having the CO_2 gas in the tube—can leisurely verify his measurements, &c., and also test the gas for CO_2 by passing up a potash ball, and, provided pure CuO is used, and the combustion tubes are clean, can absolutely depend upon first results. As far as the author's experience goes, such is not the case by the ordinary method.

When a careful determination of carbon in steel or wrought iron is required, two trials must always be made; the writer, as a rule, makes three determinations by the old method.

* CARBON DETERMINATION IN VACUO.—The author by this method is now able to estimate minute quantities of carbon in wronght iron with *far* greater certainty and accuracy than by ordinary combustion.

ON THE ESTIMATION OF PHOSPHORUS IN CAST AND WROUGHT IRON, STEEL, AND IRON ORE.

BY MR. JOHN PARRY, EBBW VALE IRON WORKS, NEWPORT, MON.

THE precipitation and estimation of phosphoric acid as pyrophosphates of magnesia being (although very accurate when conducted with care), as is well known, a troublesome and slow process, and when almost daily determinations are called for involving much labour, the author was induced to use molybdate of ammonia dissolved in measured quantities of ammonia and nitric acid and water, as recommended by Eggertz. Failing to get satisfactory results, and being informed by Mr. Snelus that a simple solution of molybdate of ammonia added to the hydrochloric solution containing phosphorus would do, tried the latter, but still with uncertain results.

In some instances the phosphorus could not be precipitated at all, even on adding a large excess of the molybdate solution.

It was found, however, that the non-precipitation of phosphorus was due to the fact that the solution was not sufficiently acid; also that *an excess* of acid considerably retarded the precipitation of the phosphorus; and it consequently occurred to the author that it would be well to add a slight excess of ammonia to the hydrochloric solution, and carefully acidify with hydrochloric or nitric acid indifferently. The latter, however, proved to be the best, and ultimately the hydrochloric solution, containing phosphorus and about one-fourth litre bulk, was treated as follows:—

1st. Ammonia added until complete precipitation of the oxide of iron, &c.

2nd. Nitric acid added in sufficient quantity to just redissolve the precipitated oxide of iron, &c.

3rd. Heated to boiling, molybdate solution added (50 grms. molybdate ammonia in one litre water).

Solution well shaken (glass flasks are most convenient for this). If the usual yellow crystalline precipitate does not appear, a little nitric acid is added, the flask well agitated, more acid added drop by drop until a distinct precipitate appears, when an additional small quantity of acid may be added.

The resulting yellow crystalline precipitate filters freely, is washed with water slightly acidulated with nitric acid, and has no tendency to pass through the filter; it is dried and weighed in the usual manner. 100 parts contain 1·63 phosphorus.

Provided the above details are strictly observed, the greater part of the phosphorus is thrown down almost instantaneously.

It has been found from repeated experience that the whole process depends on adding exactly the proper quantity of nitric acid with solutions containing about ·001 grms. phosphorus; also, that if the solution be too acid, no precipitate is shown; and on afterwards cautiously adding ammonia, an immediate precipitate is observed. On the other hand, the same result is shown when insufficient acid has been added, and a careful addition of nitric acid instantly throws down the phosphorus. With larger quantities of phosphorus this is not so marked; a notable quantity of phosphorus may, however, be easily overlooked; and the proper quantity of nitric acid to be added can only be learnt from experience.

In order to test the accuracy of the process, and also to ascertain the time required for the complete precipitation of a known quantity of phosphorus, the following experiments were made by my assistant, Mr. James Needham, on whose practical skill I could thoroughly rely—the experiments being conducted under my personal supervision:—

A solution of phosphate of iron was made, and mixed with excess of perchloride of iron. 100 c.c. of this solution contained ·01152 grms. phosphorus.

For the experiments 100 c.c. of the solution was poured into a tube 100 c.c. Burette divided into 200 parts, provided with an Erdman's float, so that the number of c.c. to be used could be accurately run out.

Expt. 1.—To 25 c.c. solution excess of ammonia was added, then acidified with nitric acid, boiled, 8 c.c. molybdate solution added, and sufficient nitric acid until precipitation. Set aside on Sand Bath 26 minutes.

Mean of five trials—Phosphorus found......·002868 grms.
" in solution ·002880 "

Expt. 2.—25 c.c. solution as above was mixed with 12 c.c. molybdate solution to ascertain whether excess of molybdate would

interfere with the accuracy of the process. Phosphorus found, ·003085 grms.

Expt. 3.—10 c.c. molybdate solution added to 25 c.c. phosphorus solution afforded ·002880 grms. phosphorus.

Expt. 4.—16 c.c. molybdate solution added to 25 c.c. phosphorus solution, on four trials afforded ·003378 grms. phosphorus.

Expt. 5.—12 c.c. molybdate solution added to 25 c.c. phosphorus solution, along with an excess of nitric acid, afforded ·001369 grms. phosphorus.

Expt. 6.—12 c.c. molybdate solution added to 25 c.c. phosphorus solution 7 c.c. excess of nitric acid. Phosphorus found, ·00271 grms.

Expt. 7.—As above, but 14 c.c. excess of nitric acid used. Phosphorus found, ·001450 grms.

The experiments 6 and 7, when set aside for many hours, gave no further precipitate.

Expt. 8.—It was thought that in experiments 2 and 4, with 12 c.c. and 16 c.c. molybdate solution, a shorter time might suffice for the precipitation of the phosphorus. Accordingly, experiments 2 and 4 were repeated, but only allowed to stand 12 minutes. Phosphorus found, ·002958 grms. experiment 2 (two trials). Experiment 4 repeated with 16 c.c. molybdate solution, and a slight excess of nitric acid, for 12 minutes. Phosphorus found, ·00295 grms.

Expt. 9.—16 c.c. molybdate solution to 25 c.c. phosphorus; solution boiled, after precipitation of phosphorus set aside, for 15 minutes. Phosphorus found, ·004254 grms.

The foregoing experiments show that great caution must be exercised throughout the whole process.

As far as the author's experience goes, it is best to add about 30 per cent. more molybdate solution than may be thought necessary; and if a considerable precipitate is at once shown, it may be considered probable that an excess of molybdate solution has been added. A slight excess of nitric acid is added, and the solution filtered as soon as the precipitate has settled, about 12 minutes being usually sufficient. In all cases the filtered solution should be re-tested for phosphorus; and if a further precipitate is shown, it is best to take a smaller quantity of the iron or steel, so that the whole of the phosphorus may be thrown down on the first addition

of the molybdate solution. Experiment 9 shows that boiling must be avoided.

The presence of lime, magnesia, alumina, and silica was found, by a series of careful experiments, not to interfere with the accuracy of the process.

It is usually stated that the presence of soluble silica must be avoided. The author, however, is unable to confirm this.

For the estimations of phosphorus in Bessemer pig, steel, and wrought iron, it is best to weigh 5 grms. of the metal. Half a grm. is sufficient of common white cinder pig; 1 grm. for unknown irons with second trial, guided by the results of the first.

ON THE REDUCTION OF PURE ANHYDROUS SESQUIOXIDE OF IRON WITH PURE CARBON IN VACUO.

By Mr. JOHN PARRY, Ebbw Vale Iron Works, Newport, Mon.

Beyond the mere fact that carbon in contact with the oxide of iron at a red heat and upwards reduces the latter to the metallic state, we have little or no information as to the part which carbon takes in the reduction of oxide of iron. It has been shown by the author's previous experiments, and by others, that carbon most carefully prepared by the ordinary methods still contained volatile matter capable of evolving gas under suitable conditions, *i.e.*, on heating in *vacuo*, or on being brought in contact at a red heat with oxides; hydrogen combining with oxygen to form water, and the remaining gases form other gaseous compounds with oxygen, the solid carbon being also taken up by the oxide in contact with it. Taking this view of the matter, it may be said the decomposition of sesquioxide of iron by the direct action of carbon only has never yet been achieved.

It occurred to the author that this might be done in vacuo, taking suitable precautions to secure sesquioxide of iron and carbon free from gas of any kind.

The mercury air-pump offered a ready means of doing this; and accordingly pure sesquioxide of iron and carbon were made by Mr. E. H. Morton, F.C.S., as follows:—

Pure sesquioxide of iron was prepared from pure oxalate of iron; the dried salt was heated in a combustion tube, in a current of purified hydrogen, until complete reduction took place. The metallic iron obtained had a steel-grey colour. It was dissolved in hydrochloric acid oxydised and precipitated by ammonia. The precipitate was well washed a great number of times with boiling water, dried at 100°, then ignited. This was found to be quite pure, with the exception of a trace of sulphur.

Preparation of carbon free from volatile matter.—This was made from white sugar, first heated until all evolution of gas had ceased, then in the full heat of a gas blowpipe, next fusing heat of iron, and lastly in vacuo, and kept in well-stoppered bottles.

The object being: 1st, to ascertain, experimentally, that on heating carbon in contact with sesquioxide of iron, the latter was reduced; 2nd, the temperature at which reducing action commenced; 3rd, the rate of reduction at known temperatures; 4th, quantity and kind of gas evolved at various degrees of heat; the author proceeded as follows:—

Expt. 1. 1 grm. sesquioxide of iron mixed with 0·25 grms. carbon was placed in a glass tube closed at one end, the other being drawn out and attached to the pump with water-joint, as shown in Frankland and Armstrong's memoir (*Chemical Journal*, vol. vi., page 90). A vacuum being first formed in the cold, the part of the tube containing the mixed sesquioxide of iron and carbon was placed in a vessel of water, which was then heated to boiling; no gas was evolved, showing that the temperature was insufficient. The tube was next placed in a bath of fused lead, gas was slowly evolved, and in 7·30 hours 3·3 c.c. gas was collected (B 760 temp. O deg.), which contained 87·2 per cent. carbonic acid, equal (the number of c.c. oxygen in 1 grm. $Fe_2 O_3$ being 209·834 c.c.) $1\frac{1}{2}$ per cent. nearly oxygen evolved.

Expt. 2. The amount of carbon required for the conversion of the oxygen contained in 1 grm. sesquioxide of iron into CO_2 being 0·1146 grms., 1 grm. sesquioxide of iron was mixed with ·13 grms. carbon, the carbon and oxide were well mixed with a spatula on a sheet of glazed paper, and transferred to a porcelain tube, the mixture being about the centre. The posterior end of the tube was closed with a well-fitting dry cork coated with melted sealing-wax, and thereby rendered impervious to air. The other end of

the tube was connected with the pump by means of a pierced, well-fitting, India-rubber cork and glass tube, the cork being coated with a thick varnish. Thus arranged, on pumping, the vacuum was found to be perfect, the whole being kept in vacuo for twelve hours previous to heating. For heating, a small gas blast furnace was fitted up, in which the tube was laid, the part containing the mixed carbon and sesquioxide of iron being placed so that the blast gas flame should play exactly upon the part containing the mixture.* By regulating the gas and air any desired temperature could be obtained and maintained; the temperature being estimated by putting small rods of different metals in the gas flame, regulating the supply of gas and air so as to just fuse the metals in the flame, it being assumed that the tube and its contents in the same flame had an equal temperature.

At a heat rather above the fusing point of zinc, but *below* that of brass, 53·52 c.c. of gas was evolved in 7 hours 10 minutes, containing 37·15 c.c. CO_2 16·37 CO=45·335 oxygen taken up from 1 grm. sesquioxide of iron, or 21·605 per cent. At the end of 7 hours and 10 minutes the gas had all but ceased coming off, and only a few bubbles were collected on further heating for three hours.

The heat was now raised to *bare* fusing of brass. Gas was evolved, as nearly as could be estimated, at the rate of 5 c.c. per hour for 1 hour 15 minutes.

The heat again raised, brass readily *fused*, but not copper. Gas came off at nearly three times the previous rate; at the end of two hours it had nearly ceased. The heat was continued for one hour longer, but very little gas was evolved.

Heat was now raised to nearly fusing point of copper. At this temperature gas was rapidly evolved, and for the first three hours and twenty-five minutes came off without the aid of the pump; after this the pump was required to collect the gas.

Total gas in ten hours, temperature raising from bare fusion of brass to *bare* fusing of copper, 51·273 c.c. CO_2 130·547 CO= 116·546 c.c. oxygen, taken up from Fe_2 O_3.

The total number of c.c. gas evolved in 17 hours 10 mins. was 235·34, of which 88·423 was CO_2, and 146·917 CO, equal 161·881 c.c. oxygen from the sesquioxide of iron, leaving only 47·953 oxygen still in combination.

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* Both ends of the tube kept cool with a small stream of water constantly running.

These experiments show—1st, that at low temperatures the reducing action of carbon is slow, also that such action is not long continued; after a certain time it practically ceases altogether; but it is also clear that at low temperatures an economy of carbon is effected, the temperature not being sufficient to convert the carbonic acid first formed into carbonic oxide. Nevertheless, it is shown that even at low temperatures a considerable amount of oxygen is liberated; thus in 7 hours 10 mins. nearly 22 per cent. of the total quantity was evolved, and when it is considered that in reduction operations on the large scale this may be considered a comparatively short time, the reducing action of carbon on sesquioxide of iron, even at low temperatures, deserves consideration. The after trials, at temperatures below the fusing point of cast iron, also show that the reduction of sesquioxide of iron by solid carbon is *rapidly* effected. Altogether, the time, 17 hours 10 mins., required for the evolution of $75\frac{1}{4}$ per cent. oxygen, is less than the time usually taken by iron ore in its descent from the top to the bottom of the blast furnace; but it must be remembered that the *whole* of the *ore* cannot be said to be in contact with carbon in the blast furnace, and, consequently, this only applies in a modified degree to the blast furnace.

The author, however, wishes this to be considered as only a preliminary paper. It is intended to carry out these experiments in *vacuo* in a more complete manner, and the exact effect due to temperature will be thoroughly tested by heating weighed sesquioxide of iron and carbon in fixed baths of the metals and their alloys, from the fusing point of zinc to that of cast iron, taking the time required until action ceases, the amount and composition of the gases evolved, from which the amount of oxygen taken up can be readily calculated.

It is also intended to carry out a similar series of experiments with various kinds of iron ore.

Next, to test the action of carbon on $Fe_2\ O_3$ in—1st, an atmosphere of CO_2; 2nd, of CO; notably the latter, in order that the results may be compared with those in *vacuo*.

QUARTERLY REPORT

ON THE

PROGRESS OF THE IRON AND STEEL INDUSTRIES

IN FOREIGN COUNTRIES.

BY DAVID FORBES, F.R.S., &c.,

Foreign Secretary to the Institute.

IV.—1872.

A. METALLURGICAL TOPOGRAPHY.

AFRICA.—The high prices which have of late ruled for such rich iron ores as are suitable for the production of Bessemer pig iron, have, as might be expected, given a considerable impulse to the exploration of the iron mines on the North-coast of Africa, and more particularly in Algeria; we find, therefore, that the exportation of iron ore from the mines of Soumah, Bouinan, and l'Arba (Atlas) to France, Belgium and the Rhine, has largely increased; very recently the Camerata Iron Company, Limited, has been formed here in England, with a capital of £50,000 divided into shares of one hundred pounds each, for acquiring the lease (for 99 years) of about 4,361 English acres of mineral land, in the district of Oulad, in Algeria, and for working the iron mines on it, with a view to the exportation of the ores.

AUSTRALIA.—According to advices of the 2nd of August this year, we learn that the smelting of iron ore has been commenced in Adelaide, where an unlimited supply of rich ore is said to occur. In New South Wales also, a deposit of iron ore of immense extent, and favourably situated near Port Hacking, has been discovered, and is being examined with the object of smelting the ore on the coast, where, it is stated, both coal and limestone can be obtained at very low rates.

AUSTRIA.—A description of the Steierdorf-Anina ironworks and collieries in Hungary will be found in the Kaernthner

Zeitschrift, 1872, No. 9, in which journal an official report on the mines and metallurgy of the Empire in 1871 will also be observed.

The newly-erected blowing machine at the ironworks at Kladno is reported to be the largest in Austria, the blowing cylinder being 9 feet 6 inches in diameter, with the same length of stroke, whilst the steam cylinder is 5 feet diameter with 9 feet stroke.

Professor A. Kerpely has just published another (the sixth) of his valuable reports on the progress of iron smelting, the present volume representing the year 1869; and although late in appearing, contains much information not generally known, and is an excellent work of reference.

Kerpely, A., Bericht ueber die Fortschritte der Eisen-huetten-Technik im Jahre 1869, nebst einem Anhange, enthaltend die Fortschritte der neuren metallurgischen Gewerbe. 6 Jahrgang. Mit 6 lithographirten Tafeln. Leipzig, 1872. Arthur Felix. 4 Th., 20 Ngr.

In the Jahrbuch der K. K. Geologischen Reichsanstalt, No. 1 for 1872, p. 27, a description, with map, is given by Frantz Ritter von Hauer, of the iron ore deposits at Eisenertz, in Styria. In these iron mines, the ores occur intercalated between beds of red sandstone and greywacke; they are of great extent and thickness, and consist of carbonates and hydrated peroxides of iron, the latter being a product of the oxidation and weathering of the former.

The following analyses by A. Patera show the general chemical composition of both varieties:—

	Spathic Carbonates.		Hydrated Oxides.	
Name of Mine.	Embla.	Barri.	Soga.	Donnersalpe.
Silica	2·80	12·48	17·04	11·60
Sesquioxide of Iron	—	—	66·10	75·08
Protoxide „	54·91	47·75	—	—
Oxide of Manganese	—	—	0·40	0·80
Carbonate of Manganese	1·60	0·99	—	—
Carbonate of Lime	3·50	1·80	trace	1·00
„ Magnesia	3·90	5·15	0·42	1·51
Carbonic Acid	34·51	30·01	—	—
Water	—	—	14·90	10·25
	101·27	98·18	98·86	100·24
Per cent. Iron in the raw ore	42·40	36·87	45·83	52·55
Per cent. Iron calcined	58·60	50·68	53·80	58·00

Belgium.—The price of iron appears at last to have reached its maximum, and some tendency to a reduction is becoming manifest, notwithstanding that sellers remain firm, whilst at the same time, purchasers are waiting in expectation of lower prices.

By a royal decree of the 14th August, a company entitled the "Hauts fourneaux d'Athus" is authorised, for the erection of one or more blast furnaces at Athus, the manufacture and sale of pig iron, and eventually the extraction and sale of iron ores, and the manufacture of coke. At the annual meeting of the Société John Cockerill, held on the 23rd October, it was stated that the number of men employed by the company was on the 6th October, 1872, 8,556 as compared with 8,192 on the 30th June, 1871. Numerous coke ovens of the Appold construction had been erected or were in course of construction, and the foundations of the new blast furnace for producing Bessemer pig had been commenced, as well as the erection of the converters, boilers, and machinery. Special attention is being directed to increasing the turn out of steel, the annual value of the production of steel from their works having already increased from £127,000 in the year ending 30th June, 1871, up to £212,109 this year, and will be augmented in a still greater degree, as soon as the new blast furnaces and Bessemer works are completed.

A new rolling mill for large flats is expected to be soon in operation at the works of M.M. Dewerbe and Cie, at Jemappes, and a three-high roll plate mill on the Lauth system is spoken of as about to be put up by the Ougree Iron Works Company.

Continual complaints are being made of late as to the extreme irregularity of the arrival, and the depreciation in the quality of the Spanish iron ores.

Danks' rotary puddling furnaces are being erected at the forges of M. Dallemagne, at Schlessin, near Liege, and the reports of M. Taskin and Tahon were ordered to be printed immediately by the Association des Maîtres de Forges, for the use of the various works. This report has also appeared in the *Moniteur des Interêts Materiels* and the September number of the *Bulletin de L'Union des Charbonnages &c de la Province de Liege* contains this report in full, illustrated by lithographic plates.

The importation of iron into Belgium, which during the first six

months of 1871 amounted to 46,000 tons, has increased during the corresponding period of this year to 78,000 tons, and in the month of June alone it rose from 16,000 up to 20,000 tons. The most remarkable feature in this augmentation is that Germany (the Zollverein), which in 1871 only furnished 993 tons, stands this year at 6,777 tons, or more than six times as much as before, and although rails have never before been imported into Belgium from Germany, this item stands this year at 1,540 tons, of which 275 tons were received in the month of June alone, indicating plainly that since the conclusion of the war, Germany is likely to become a formidable rival as an exporter, and to play a very different part in the metallic markets of the continent in the future. France figures for 3,500 tons, and England for 60,000 tons, countries which the preceding year stood only at 1,200 and 39,000 tons respectively.

The results of the exportations during the first six months of this year, show a rise to 143,000 tons from 106,000 tons in 1871; the month of June 1872 standing at 27,400 tons instead of 27,000 tons last year. As regards the countries to which the iron was exported, the quantity forwarded to Germany (the Zollverein) is diminished from 51,000 tons to 38,000 tons; but to England on the contrary it increased from 5,000 tons to 13,000 tons; to France from 4,000 tons to 14,000 tons; to Austria from 8,000 tons to 12,000 tons; and to the United States of America from 3,000 tons to 12,000 tons. Whilst the total exportation of rails from Belgium to other countries has remained almost stationary, that of crude pig iron has increased from 14,000 tons to 20,000 tons. The grand total shows that 37,000 tons more have been exported during the first six months of this year than during the corresponding period in 1871; but when it is remembered that 32,000 tons more were imported this year, the final result is that the actual progress made in the Belgian iron trade is altogether insignificant, and appears the more so when the extreme high prices and excited condition of the iron market are taken into due consideration.

We have received the official tables of the importation and exportation of Iron and Steel &c., from which we extract the following data given in metrical tons:—

IMPORTS DURING THE FIRST EIGHT MONTHS.

IRON ORES and FILINGS from—

	1872. Tons.		1871. Tons.		1870. Tons.
Sweden and Norway	2	...	$\frac{4}{10}$	...	—
Germany (Zollverein)	395,554	...	310,398	...	274,400
Netherlands	9,820	...	6,398	...	11,775
England	72	...	—	...	322
France	171,037	...	78,680	...	137,632
Spain...	4,395	...	1,012	...	—
Other countries... ...	—	...	120	...	—
	580,880	...	396,489	...	424,129

IRON—Cast, wrought, and manufactured, of all kinds, to—

	1872. Tons.		1871. Tons.		1870. Tons.
Sweden and Norway	1,959	...	1,534	...	992
Germany (Zollverein)	10,790	...	1,225	...	2,291
Netherlands	9,202	...	3,507	...	4,649
England	73,957	...	49,907	...	54,750
France	4,490	...	1,730	...	2,856
Other countries.........	59	...	41	...	2
	100,459	...	57,946	...	65,543

STEEL—Wrought, cast, and manufactured, of all kinds, to—

	1872. Tons.		1871 Tons.		1870. Tons.
Germany (Zollverein)	1,999	...	1,221	...	1,020
Netherlands	39	...	16	...	68
England	4,512	...	3,794	...	2,040
France	1,329	...	1,636	...	7,246
Other countries ...	1,374	...	59	...	102
	8,147	...	4,091	...	3,231

EXPORTS DURING THE FIRST EIGHT MONTHS.

IRON ORES and FILINGS to—

	1872. Tons.		1871. Tons.		1870. Tons.
Germany (Zollverein)	31,758	...	50,733	...	22,605
Netherlands	25,750	...	—	...	6,602
England	—	...	—	...	12
France	66,259	...	65,083	...	98,096
Other countries ...	—	...	—	...	80
	123,767		115,816		127,396

IRON—Cast, wrought, and manufactured, of all kinds to—

	1872. Tons.		1871. Tons.		1870. Tons.
Russia	11,258	...	12,081	...	45,611
Sweden and Norway ...	802	...	244	...	1,849
Denmark	232	...	389	...	75
Germany (Zollverein) ...	51,994	...	71,142	...	34,901
„ (Hansetowns) ...	4,600	...	4,094	...	2,609
Netherlands	32,072	...	22,520	...	16,197
England	18,309	...	8,425	...	8,480
France	18,337	...	8,196	...	28,066
Portugal...	398	...	80	...	—
Spain	4,624	...	604	...	2,916
Italy	3,974	...	5,751	...	6,669
Switzerland	6,527	...	276	...	2,808
Austria	13,564	...	11,777	...	1,197
Roman States	172	...	467	...	35
Turkey	3,950	...	7,888	...	16,738
Egypt	3	...	17	...	1,493
Mexico	465	...	154	...	9
United States	16,775	...	7,651	...	6,953
Cuba and Porto Rico ...	1,013	...	1,893	...	1,337
Brazil	1,093	...	458	...	361
English Colonies	1,136	...	91	...	—
Uruguay...	234	...	49	...	44
Argentine Republic ...	462	...	584	...	111
Chili and Peru	294	...	549	...	273
Other Countries	105	...	8	...	76
	192,401		165,396		178,817

STEEL—Cast, wrought, and manufactured of all kinds, to—

	1872. Tons.		1871. Tons		1870. Tons.
Russia	49	...	189	...	31
Germany (Zollverein) ...	386	...	11	...	10
Netherlands	87	...	39	...	10
England...	10	...	652	...	32
France.	172	...	23	...	114
Spain	—	...	10	...	1
Italy	52	...	957	...	63
Turkey	89	...	1,475	...	—
Switzerland	327	...	—	...	—
Austria	22	...	$\frac{1}{10}$	...	—
Other countries	65	...	68	...	59
	1,289		3,398		1,358

If now we take into consideration the relative value of the imports during the first eight months of this year, as compared with that of the corresponding period in 1871, we shall find an increase in the value of the steel in the form of bar, sheet, and wire imported into Belgium, amounting to 1,729,878 francs, and on manufactured steel of 1,392,938 francs, or together about £124,912; also of 4,978,562 francs, or £199,142, on iron ores, and of 2,903,071 francs or £116,123, on pig and scrap iron.

On the other hand, amongst the exports we find that Belgium has exported pig and scrap iron, wrought iron, and iron in manufactured form, together exceeding in value the similar products in 1871 by 3,975,855 francs, or £159,030—the respective amounts being pig and scrap iron 991,347 francs, wrought iron 1,033,398 francs, and manufactured iron 1,951,110 francs; against which, however, we have to note a diminution in the value of the quantity of rails exported of 2,178,608 francs, or £87,144, which is the more remarkable when the extremely high prices of rails which have ruled this year are taken into account.

CANADA.—The Hull iron mines, situated in the province of Ontario, well known for their rich and pure magnetic ore, are reported as having changed owners, and been purchased by some English and American capitalists, who propose working them with vigour. During the present season about 12,000 tons of iron ore had been extracted from the mines. The Canada Steel Works are

also said to be commencing operations, using as ore the black magnetic iron sands, which from their being free from either sulphur or phosphorus, are expected to yield a superior product.

France.—The condition of the iron trade in France at this moment appears to be very prosperous; all the works are in full operation, and the prices keep up. Fears are, however, entertained of a scarcity of combustible during the winter months.

The make of iron in France is increasing, and the greatest activity is everywhere displayed. It is reported that the blast furnaces of Wendeuvre, Louvemont, and Pancy, are to be blown in shortly, and several new furnaces are being put in operation in Compté.

At Chamauilley, in the Haute-Marne, a new rolling mill is about to be erected, and it is reported that Forges d'Eurville have leased the blast furnace at Eclaron, which has been standing idle during the last ten years.

The French Government have wisely taken advantage of the present high prices of iron to dispose of all the old iron in the French arsenals and Government workshops, to the amount of fifty millions of francs.

The importation of pig and scrap iron during the first seven months of this year was 105,000 tons, as compared with 109,000 tons in the corresponding period of 1870. In this return, however, the quantity imported free of duty in 1870 was 96,000 tons, against only 42,000 tons this year. In wrought iron the importation has decreased considerably, being 24,080 tons, as compared with 48,000 tons in 1870, but of these quantities the duty was only paid on 2,600 tons in 1870, against 9,700 tons this year.

The total exportation during the first seven months of this year is given at 111,000 tons, as compared with 130,000 tons in the same period in 1870.

The Customs House returns for the first eight months of this year show 106,201 tons pig and scrap iron imported, against 96,353 tons in 1869; 29,260 tons bar and sheet iron, against 45,541 tons in 1869. The total exports of cast, wrought, and manufactured iron of all kinds is given at 138,687 tons in the first eight months of 1872, as compared with 38,076 tons during the corresponding period in 1869.

The Bessemer steel production in France is every day becoming

more extensive; the Compagnie des Forges de Denain et d'Anzin are establishing Bessemer works, and if we believe the *Bulletin du Comité de Forges*, this company has concluded an agreement with the Compagnie du Nord for the sale of 80,000 tons steel rails, to be delivered in the course of the next ten years. Bessemer converters are also about to be put up by the Compagnie d'Orleans at Rouen, at the Rouen Forges, which were purchased last August by this company.

GERMANY.—A paper on the deposits of iron ore in the Harz, by F. von Ducker, will be found in the *Berggeist*, No. 84, in which the mines are classified under the two heads of the hematites of the Western Harz (Osteroder-Altenauerzug), which are found at the junction of graywacke slates with the greenstones, and as beds and lodes in the Devonian strata at Elbingerode and Huettenrode; and, second, the sedimentary oolitic beds in the Liassic formation to the northern end of the Harz Mountains.

W. Hupfeld, manager of blast furnaces in Prevali, has lately published some remarks on the Rhenish and Westphalian blast furnaces in 1871—"Reisenotizen ueber die Lage der rheinisch-Westphaelischen Hohofenindustrie 1871," from which we extract the following:—According to him, the blast furnace practice in the Siegen district is now against large dimensions in the furnace, and whilst the upper portion of the furnace is made comparatively large the hearth is strongly contracted, for the reason that most of the Westphalian coke is very weak, and the ore so easily reduced that it does not require being longer than 15 to 18 hours in the furnace, for which reason also, an increased capacity of the furnace is not required. In erecting new furnaces, the usual cross channels (or St. Andrew's cross as they are generally called) below the hearths are no longer used, but the whole is made solid with brick-work set in cement. Water breasts are employed, and the water-tuyeres are now made of bronze, which are considered to last much longer than iron ones, and are manufactured by Dango and Dienenthal, in Siegen. In general, horizontal blowing machines are employed in this distiict. When heating with the furnace gases, from 20 to 25 square feet of boiler surface is exposed to the flame for each effective horse-power, and it is stated that in Prevali a saving of 60 per cent. was effected by increasing the heating surface from 16 to 32 square feet per horse-power. Suspended pipe

air-heating apparatus are preferred, the pipes being elliptical, 10 feet long, and internally 16 inches by 4 inches wide, the temperature attained by the air is from 900° to 1,050° Fahrenheit; higher temperatures are often reported, but are not to be relied on, being probably due to incorrect pyrometers. This class of heating apparatus, owing to the pipes being able to expand and contract freely, does not tear itself to pieces, and is reported as working much better than on the older system. The ores smelted are spathic carbonates and brown hematites; the former, when calcined seldom contains more than 46 per cent metallic iron, but contains more manganese than Nassau iron ores, which for this reason and because they are less easily reduced, are cheaper. Only the spathic ores are roasted, which is done in small kilns which calcine from 10 to 15 tons each per day, and require 10 per cent. fuel (coke small and refuse). The coke employed is from the Ruhr, and is extremely weak and irregular in consistence, and broken up, so that it is not suited for high furnaces. The pressure of the blast is from 3 to $3\frac{1}{2}$ lbs. per square inch, the tuyeres being six in number, and three inches in diameter.

The Ilseder Works at Peine smelt limonite (Bohnerze), which is extremely cheap, but, unfortunately, even after careful sorting, contains so much phosphorus that its value is very low, notwithstanding its being rich in manganese. When smelted, the furnace yield is from 75 to 87 tons white pig; and 1 ton pig requires $1\frac{1}{10}$ tons coke, using $2\frac{1}{4}$ to $2\frac{1}{2}$ lbs. pressure of blast, and which is heated to the temperature of 7 50° Fahrenheit. The Ilsede pig iron most approaches the Luxembourg in commercial value. The chemical composition of both these cast-irons as well as of the slag produced along with them, will be seen from the following analyses:—

PIG IRON.

	Luxembourg.	Ilsede. White Iron.	Spiegeleisen:
Iron	94·97	92·000	90·74
Manganese	0·22	2·144	3·35
Silicon	0·91	0·133	0·14
Phosphorus	1·82	2·895	2·82
Sulphur	0·08	0·101	—
Carbon	2·00	1·170	2·95
	100·00	99·443	99·90

Blast Furnace Slag.

	Luxembourg:		Ilsede.
Silica...	42·49	...	28·01
Alumina	16·02	...	11·30
Protoxide of iron	2·89	...	0·75
— of manganese	0·59	...	11·71
Lime ...	34·39	...	41·49
Magnesia	2·31	...	2·14
Sulphur	0·41	...	2·52
Phosphorus	0·90	...	1·32
	100·00		99·24

India.—According to the *Madras Times*, of July 18th, it appears that the Indian Government is directing attention to the utilization of the iron ore of the district, which is known to be of superior quality, on account of the success of the trial borings at Cummum having shown symptoms of good coal.

New Zealand.—Considerable deposits of red hematite iron ore have been discovered on the estate of the Wharekawa Coal Company, in the province of Auckland, which, upon being analysed by Mr. J. A. Pond, of Auckland, was found to contain an average of 52½ per cent. metallic iron. We hear of another "attempt" to smelt the Taranaki iron sand, made at Mr. Vivian's foundry, with the result that "the metal was made to run successfully." It seems that the New Zealanders are not yet tired of playing at iron-smelting!

Nova Scotia.—The Acadia Iron Works have been recently purchased by Sir Hugh Allen from the Intercolonial Iron and Steel Company for the sum of £50,000, and are now to be considerably enlarged. The original owners of these works were Messrs. C. D. Archibold & Co., who sold them to the Acadian Charcoal Company, by whom they were leased in 1865 for seven years to the Intercolonial Iron and Steel Company, with option of purchase within that term at a fixed sum. This option has lately been taken advantage of by the latter company, who have now, as above-mentioned, resold it for, it is stated, a sum which is about one-half what the property has cost. It is reported that Mr. Ellershausen is about to erect charcoal blast furnaces on his property, and that

Mr. Prentice is about to form a company for erecting coke blast furnaces to smelt the hematite, specular, and spathic ores from his mines, with the object of producing Bessemer steel for the manufacture of rails, employing coke made from the Nova Scotian coal, which can be obtained at 9s. per ton, for this purpose.

PORTUGAL.—The Government official journal of the 24th October contains particulars of various concessions granted for iron mines, from three-quarters of a mile up to five miles distance from a shipping-place on the River Mira. The iron ores in these deposits are stated to be in immense quantity, and to cost extremely little for extraction. The analysis of one of the ores, which is a hydrated peroxide of iron, showed it to contain 79 per cent. oxide of iron, 4 oxide of manganese, and 13 per cent. water; whilst another, which is a manganiferous oxide of iron, contained as much as 30 per cent. oxide of manganese, along with 60 per cent. sesquioxide of iron, and would appear to be well suited for the production of spiegeleisen.

RUSSIA.—From the Customs returns it appears that the importation and exportation of iron during the first eight months (1st January to 1st September) of this and the last year were respectively as follows:—

	First Eight Months 1871.		First Eight Months 1872.	
Imports.	Russian Pouds.	English Tons.	Russian Pouds.	English Tons.
Pig iron	1,724,886	27,806	1,089,295	17,561
Rails	5,022,784	80,972	2,676,500	43,148
Plate and sheet iron	783,118	12,625	835,395	13,468
Other wrought iron	3,181,681	41,292	2,324,533	37,474

As regards the exportation, we have no details, but only the statement that the exports of iron of all kinds during the first eight months of this year amounted to 151,451 pouds, or 2,442 English tons, against 166,551 pouds, or 2,685 English tons, in the corresponding period in 1871.

The regulations for the Compagnie de la Fabrique de Rails d'Azov, which was established by the Councillor of Trade, Samuel Poliakow, have been sanctioned by imperial decree of the 16th August, and have been published in the *Bulletin des Lois*.

The Russian (Vyksounsky) Iron Works Company, after a long experience of litigation and other difficulties, appear to have got

into smoother water, and at the recent annual general meeting, held on the 1st November, the chairman announced a ten per cent. dividend for the year, and held out the prospects of a brighter future.

As a proof that the Russians are advancing in the manufacture of iron may be mentioned, the armour-clad ship "Peter the Great," which is stated to be the most formidable ship of war ever constructed, and which, according to Russian accounts, is built entirely of Russian materials and by Russian workmen. Both the armour plates and the plates for the hull of the vessel are of Russian manufacture, the latter, which are of charcoal iron, being manufactnred at the Imperial Iron Works at Petrozavodsk, on the Onega and Kolpino. The engines of the vessel were made in St. Petersburg, and the armament is also of Russian manufacture, the cannon being cast of Russian steel tempered in oil, and reported to be superior in strength and power of resistance to any yet furnished by Krupp or the Woolwich arsenal.

Very recently, however, some rumours have reached us that the steel cannon of large calibre, of Russian make, have not in practice come up to the standard hitherto accorded to them in Russia, and that orders have been given to reduce the charge of powder in future as a necessary precaution.

Spain.—Much excitement has lately been occasioned amongst all those interested in exportation of iron ores from Spain, by the declared intention of the Spanish Government not to exempt iron ore from the operation of the new tariff, which imposes a duty of 4 reals (about 10d. English) per ton on all exports. As, according to previous legislation, it was provided that no duty whatever should be imposed upon the exportation of minerals before the end of the year 1880, this appeared to be a manifest breach of faith towards the mining interests of the country. A deputation of the principal ironmasters and others interested in the importation of Spanish ores into England, accordingly waited upon Earl Granville at the Foreign Office, to memoralise his lordship to protest against this breach of faith as injurious to the interests of the iron trade, and it is satisfactory to learn that the Spanish Government have withdrawn the proposition, and confirmed the law exempting iron ores from any export duty before the expiration of 1880.

A new weekly periodical, dedicated to mining and metallurgical

interests, has made its appearance in Madrid, called *La Mineria*, the first number having been published on the 15th of August this year.

The Eldorado Syndicate, Limited, has been recently formed, with a capital of £100,000, divided into shares of ten pounds each, for the purchase of the Eldorado iron mines at Malaga.

According to the *Tiemps*, the Royal decree of the 31st August, granting to an English Company the privilege of forming, at their own cost, a new harbour at the mouth of the river of Bilbao, has been received with great disapprobation by the commerce of the city of Bilbao, it being feared that such a new port would in time succeed in attracting the trade of the district to itself. A deputation, consisting of Messrs. Murga and Mugártegui, has consequently been sent to Madrid to protest against this concession of the Government.

According to *La Mineria*, of the 15th November, a strike has taken place amongst the waggoners, who bring down the iron ores from the mines of La Pena, Miravella and the vicinity, to the shipping places on the river of Bilbao.

The Sommorostro Iron Ore Company are constructing one of Hodgson's wire tramways, guaranteed to bring down five hundred tons of ore per day from their mines, which lie above and immediately outside the city of Bilbao.

From the Santander district, we learn that the greatest activity is now being displayed in opening up new iron mines and arranging means of transport for the ores to the coast. To Don Raman Perez del Molina has been conceded the formation of a railway, which, starting from the great deposits of iron ore at Sopuerta, situated on the boundary between the provinces of Biscay and Santander, runs down to Castro Urdiales, or other convenient point on the coast; this line requires two tunnels, and is between seven and eight English miles in length.

Another concession is for a mineral railway, of about six-and-a-half miles in length, which starts from the iron mines of Outon and passes through the mines of Salta Caballo, in Mionio, which belong to Messrs. Ybarra Brothers, terminating also at Castro Urdiales. A new pier, with projecting wharfs, for shipping the iron ores from Santander, has now been commenced, and will be connected with the railway station and have three lines of rails.

A company, called the "Sociedad la Paulina," has commenced to open out a number of concessions of iron ore on the hills of Comanga, and has constructed a horse tramway of about two miles in length down to the Guarnizo Station on the Alar and Santander Railway; this company calculates to export about 60,000 tons per annum.

In Belgium, complaints are being made that the quality of the Spanish ores now imported has become much inferior of late, and from what we can learn, this is also the case with many of the shipments received in England, the exporters evidently taking advantage of the late extraordinary demand for this class of iron ore, to send all that comes first to hand, without any care being bestowed upon its selection, before shipment.

SWEDEN.—The iron trade of this country has probably never been in so prosperous a condition, and all the Swedish ironworks have used every effort to increase their production, whilst the prices continue as high as they have been during the last half year.

A rotary puddling furnace on the Danks' system is being erected at the Motala Works, but, as a rule, the Swedish ironmasters have come to the conclusion that the future of the Swedish iron industry is not associated with the manufacture of wrought iron, but that it is dependent entirely upon the development of the Bessemer system of steel making, which enables them to produce, direct from their blast furnaces, a soft steel (or rather homogeneous iron) containing as low as 2-tenths of a per cent. or less of carbon, and combining in itself the good qualities of both iron and steel, more especially for boiler plates and similar uses, for which purposes there is now an unlimited demand for the Swedish product. The Fagersta and Vestanfors steel works, belonging to Mr. Aspelin, show, in the Copenhagen exhibition, a magnificent series of their Bessemer products of this character, commencing with the crude materials such as the raw and roasted ores, limestone, cast iron, &c., and ending with the finished products in the shape of tram rails, axles, cranks, springs, buffers, tools of all descriptions, and especially gun barrels, for which this class of soft steel or rather iron, appears to be especially adapted, as shown by the numerous certificates attesting to their strength when subjected to the proof. These specimens are accompanied by statements showing the chemical composition of the products in the different stages of the manufacture, some of

which are thought to be of sufficient interest to warrant their being reproduced here.

Commencing with the blast furnace, which is driven with charcoal, we find that the average chemical composition of the "charge," that is, the mixture of the iron ores, along with the limestone which is employed as flux, is reported to be as follows:—

Silica	11·93	
Alumina	2·50	
Lime	7·51	
Magnesia	2·76	
Protoxide of Manganese ...	5·63	
" iron	19·76	Equivalent to 46·09 per cent. metallic iron.
Sesquioxide of iron ...	43·89	
Carbonic acid	6·02	
Phosphoric acid	0·13	
	100·13	

The above "charge," which contains 46·09 per cent. metallic iron, yields, upon smelting, between 49 and 50 per cent. cast iron, which is tapped direct from the blast furnace into the Bessemer converters, and has the following average composition:—

Iron	89·962
Manganese	4·491
Silicon	0·771
Carbon combined...	3·460
" graphitic	1·289
Sulphur	trace
Phosphorus	0·027
	100·000

along with blast furnace slag of the composition, shown below:—

Silica	41·96
Alumina	7·02
Lime	25·04
Magnesia	17·75
Protoxide of Manganese	6·57
" Iron	0·23
Alkalies and loss in analysis	1·43
	100·00

The Bessemer steel produced from the above iron is naturally more or less hard in proportion, as the "blow" is shorter or longer in duration, and the following analyses show the chemical composition of the four different classes of steel employed for the uses specified :—

	Carbon.	Silicon.	Manganese.	Phosphorus.	Sulphur.
(*a*) Steel for soft plates, axles, &c.	0·085	0·008	——	0·025	——
(*b*) ,, gun barrels, axles, &c.	0·25	0·036	0·234	0·022	——
(*c*) ,, softer tools, &c.	0·70	0·032	0·256	0·223	——
(*d*) ,, harder tools, &c.	1·05	0·067	0·335	0·028	——

The following figures show some of the results obtained by experiments made at D. Kircaldy's works in London, for the purpose of ascertaining the mechanical properties, &c., of the Fagersta steel :—

A. Pulling Stress—length nine diameters.

Bars Stamped.	Test No. B	Elastic Stress per sq. inch. lbs.	Ultimate Stress per sq. in. lbs.	Ratio of Elasticity to rupture. per cent.	Contraction of Area at fracture. per cent.	Ultimate Permanent Extension. per cent.	Effects.
0·3	1178	43,000	59·528	72·2	62·61	11·2	Fractured slowly.

B. Thrusting Stress—length one diameter.

Test No. B.	Elastic Stress per sq. inch. lbs.	Ultimate Stress per sq. inch. lbs.	Ultimate Permanent Depression in Inch.	Ultimate Permanent Depression in per cent.	Effects.
1100	65,000	200,000	·222	19·7	Bulged.
1130	62,000	200,000	·290	25·7	do.
1140	56,000	200,000	·314	27·8	do.

Length two diameters.

1101	58,000	184,000	·702	31·2	Skewed.
1121	59,000	156,000	·410	18·2	do.
1141	52,000	156,000	·638	28·4	do.
1171	43,000	123,000	·092	40·9	do.

C. Twisting Stress—length of lever 12 inches, length for torsion eight diameters.

Test No. B	Elastic Stress per sq. in. lbs.	Ultimate Stress per sq. in. lbs.	Ratio of Elastic to Ultimate. per cent.	Ultimate Torsion. 1 turn—1000.	Effects.
1129	1,075	2,188	49·1	0·897 1·255	One end fractured. Other end do.
1179	760	1,545	49·2	3·283 3·725	One end fractured. Other end partly so.

D. Bulging Stress.

Stamped.	Test No. B.	Thickness of Plate.	Stress in Pounds.—Bulged, Inch. 5,000	25,000	50,000	75,000	100,000	Ultimate Bulge.	Ultimate Stress.
0·3	1643	0·25	·208	·987	1·74	2·39	——	3·68	99·760
0·3	1648	0·25	·211	1·03	1·77	2·42	——	4·40	99·432

The numbers stamped on the steel represent the percentage of carbon, or, in other words, the degree of hardness; it being customary in Sweden to classify the steel according to the percentage of carbon—the more the carbon the harder is the steel.

In a communication to the Royal Academy of Science—"Tefroit och Tefroit-arter; i Svenska jernmalmer af L. I. Igelström, Oefersigt af Kongl. Vet-Akad Forhandl."—vol. 28, p. 1169, the mineralogist Igelström shows that the manganese contained in the Swedish ores, instead of being in the state of carbonate or oxide usually imagined, is in reality a compound silicate, either as Tephroite or Knebelite. The latter of these minerals has been found at Dannemora, Schisshyttan, and Hillaeng; whilst he has recently discovered the former intermixed with the ores of Sjogrufrau, as well as at Pajsberg, and in large masses in the limestone at Langban.

Tasmania.—For the first time, we hear that there is a probability of the iron manufacture being introduced into Van Diemen's Land, as a private company has just been formed in Melbourne for the purpose of working a rich and extensive deposit of brown hematite discovered near Launceston, in the northern part of the island, which is said to contain more than 70 per cent. metallic iron. Four hundred acres of land have been secured from the Government by the company, and works for smelting the iron ore are to be erected forthwith at Yorktown. After an examination of the different coals at command, the company have decided on using those from the Mersey and Deloraine Tramway Company's collieries, as being, in their opinion, the most free from sulphur, containing the smallest percentage of ash, and in all respects the best adapted for smelting iron of any of the Australian coals submitted by them to chemical examination.

Turkey.—It is reported that the Government of this country has in contemplation the erection of smelting works and forges for the reduction and manufacture of iron, from the lode of red hematite iron ore recently discovered at Beicos, for which purpose coal from the collieries at Hericli is proposed to be employed.

United States of America.—Speculations on the approaching exhaustion of the British coal-fields and iron mines, and the time when the English manufacturers will be obliged to send to the

United States for both their iron and coal, appear to be quite in fashion in that country. In a late number of the *New York Daily Bulletin*, after a long preamble proving, to the entire satisfaction of the writer at least, that this must be the case eventually, the concluding sentence continues: "But however this may be, it is in our power to control the iron trade of the world as absolutely—during the next half-century at least—as Great Britain has controlled it during the past quarter of a century; and whether we shall seize upon and profit by this magnificent opportunity or not, depends upon the energy and enterprise displayed in the development of our coal and iron resources, and the increase of our furnace capacity." Most probably the ironmasters in England will look upon these expectations as somewhat premature.

The Cambria Iron Works, at Johnstown, Pennsylvania, on the Pennsylvania Railroad, west of the Alleghanies, took fire on the 12th October, and were in greater part destroyed, with the exception of the steel works and furnaces; the loss has been estimated at upwards of £80,000. The Cambria Works were the largest in America, turning out about 250 tons per day, and the buildings alone covering some 20 acres of ground; more than 3,000 workmen have been thrown out of employment for the time by this disaster, but the rebuilding of the works has already commenced. Another fire, supposed to have originated from friction in the machinery, has also taken place at South Trenton, on the banks of the Delaware, in the rolling mills of Messrs. Cooper, Hewitt, and Co., the entire rail and girder mill being consumed before the progress of the flames could be arrested.

The general impression in the States seems to be that prices have now reached their maximum, for which reason orders are being generally held back. In some parts of the country, the demand is not equal to the supply, hands are abundant, and wages have become lower than ever. A number of patents have been taken out for different forms of rotary puddling furnaces.

New works are still being erected and extensions made to the older establishments in all parts of the country. Thus in Pennsylvania, at Sharon, the Jackson Iron Company are erecting a blast furnace, and at Pittsburgh, Messrs. Singer, Nemick, and Co., are making extensive additions to their steel plant; this firm are using

Lauth's three-high plate and sheet rolls, and are now about setting up a 20-inch train on this system.

The West Bethlehem Iron and Steel Company has also been formed, and a new furnace lately put into blast by the Emans Iron Company, this furnace being 65 feet high, 16 feet in the boshes, and turning out 16 tons pig iron per shift. The rolling mill at Pencoyd, on the west side of the Schuylkill, is being much enlarged, a train of three-high rolls and four double action steam hammers being added. At Reading, a second blast furnace, 50 feet high and 14 feet across the boshes, is being put up by Messrs. Bushing, and the Allentown Iron Company have just completed one 60 feet high and 17 feet diameter at the boshes, which is calculated to turn out 200 tons of pig iron per week; a blast furnace is to be built at West Middlesex, and the citizens of that town have offered to give the sum of £2,000, along with five acres of land, to any one who will erect a rolling mill there.

The McNeal Coal and Iron Company, of Philadelphia, have suspended payment, with liabilities which are reported to exceed £200,000; no cause for the stoppage has been as yet made known.

Attention is being directed to the working of the great deposits of iron ore situated in Bedford, County Pennsylvania, known by the name of the "fossil red hematite ore," and containing from 40 to 50 per cent. metallic iron. This ore occurs as beds in the Silurian geological formation, and has already been smelted in blast furnaces erected by the Kemble Coal and Iron Company in 1869. Coal can be had from the Broad Top coal basin at a very low rate, and the distances from the collieries by rail to Bloody Run and Bedford, where the blast furnaces are proposed to be placed, are respectively fourteen and twenty-two miles; the estimated cost of making grey pig iron at these places is given as follows:—

	Bloody Run.		Bedford.
Ore, 45 to 50 per cent., say $2\frac{1}{2}$ tons at $1\frac{1}{4}$ dollars	3·75	...	3·12
Coke, $1\frac{1}{2}$ to $1\frac{3}{4}$ tons	7·00	...	7·00
Limestone..	·60	...	·60
Labour, furnace expenses, repairs, &c	4·45	...	4·00
Dollars	15·80	...	14·72

An elaborate report on the property, dated September 1st, 1872, has been published by Dr. Kimball, who estimates the quantity of

ore in the so-called " Fossil ore seam" to exceed thirteen millions of tons, and upon whose authority the preceding data are given.

In Ohio, the Girard Rolling Mill Company has recently been organised with a capital of £20,000, and the works are expected to be in operation by the commencement of 1873. A new concern, with a capital of £30,000, called the Franklin Iron Works Company, is also reported from Cleveland, and the Aultman Steel Company are fitting up a rolling mill for manufacturing plate, sheet, and machine steel. The Glasgow and Port Washington Company, in Ohio, are erecting several new blast furnaces at Ulrichville; and at Columbus, the Franklin blast furnace, 62 feet in height by 17 feet across the boshes, is in course of erection, and is to be provided with all the latest improvements, including closed top; the four hot blast stoves and the boilers being heated by the waste gases from the furnace.

In the State of New York, at Troy, Messrs. J. A. Burden and Co. are constructing a new blast furnace, to be supplemented by a new forge containing thirteen additional puddling furnaces, and at Conshobocken, Messrs. J. B. Moorehead are also building a new blast furnace, provided with Ford's patent hot blast apparatus, which is about to be tried for the first time in the United States. At Buffalo, a new company, entitled the Niagara River Iron Company, have already erected two blast furnaces, and the Wadsworth Iron Works, which some time ago suspended operations, are now again in full work, which is also the case with the Shepard Iron Works, which stopped lately, owing to their inability to complete contracts at the old prices, in face of the great advance in the cost of raw materials.

In Wisconsin, the National Iron Company, whose head-quarters are at Depere, in which neighbourhood they have nine blast furnaces in operation, are about to increase the number, and at Milwaukee, a blast furnace, 16 feet in the bosh, is being put up, the castings being furnished by Messrs. Dickson, Marshall and Co., of Pittsburgh.

In Michigan, the Carr Iron Company has been launched at Marquette, to open out an iron mine containing, it is stated, an inexhaustible supply of good ore.

In Tennessee, at Knoxville, Messrs. Buckley and Company are constructing a blast furnace, 15 feet across the boshes, and an

extensive tract of coal and iron land has been purchased by other capitalists for the purpose of working the mines, and erecting blast furnaces for smelting the iron ore.

In Missouri, on the Osage river, a blast furnace, calculated to turn out 200 tons pig iron per week, is in course of construction, whilst others are to be erected at the Union Iron Works, at Carondelet; these works having recently been made over to a New York firm. At this place the Vulcan Iron Company pay their workmen by the ton of pig iron turned out of the furnaces, which system is reported as having greatly increased the make. This company has also a new blast furnace so far completed as to be ready for blowing in at the new year.

In a recent report from the State geologist, a description is given of the so-called iron mountains of Missouri. According to this, Shepard Mountain is 660 feet high; Pilot Knob 1,118 feet high, with an area of 360 acres, if measured at 518 feet below the summit; and Iron Mountain has an elevation of 220 feet, with a basal area of 500 acres; these three mountains are considered to contain above 200 millions of tons of iron ore above the level of the surface around. Some of the mines of iron ore of this district have recently been purchased by the Isabella Furnace Company, of Pittsburgh.

In Indiana, a company, called The Indiana Iron and Steel Works Company, with a capital of £200,000, divided into shares of £10 each, has been incorporated for the manufacture of iron and steel, in addition to working collieries.

As an example of the strong inducements so often held forth in the United States to such capitalists as will invest in iron-works, we append the copy of a circular recently sent to the Foreign Secretary:—

"The Cincinnati and Terre Haute Railroad Company, desirous of enlisting the attention of manufacturers to the advantage of locating manufacturing establishments upon the line of their railway, will give any rolling mill or blast furnace company so locating forty (40) acres of grounds for works, and the coal in one hundred (100) acres of Clay or Owen county, Indiana, block coal field; the ore from one hundred (100) acres of the Hardin, Pope or Massac county, Illinois, brown hematite beds, and agree to furnish them with all orders for merchant iron required for the railways'

use for a period of two years." "Circulars descriptive of the manufacturing points upon the line of railway will be mailed to any address upon application to

MATT P. WOOD,
General Superintendent, C. and T. H. R.R., Terre Haute, Indiana."

In Connecticut, the Bridgeport Steel Company has been organised with a capital of £30,000, and the Shepang Iron Company with a capital of £15,000.

B. METALLURGICAL TECHNOLOGY.

ACTION OF CHARCOAL AND IRON ON CARBONIC ACID AT A RED HEAT.—It has long been taken for granted that, at a red heat, charcoal has the power of decomposing carbonic acid by reducing it to carbonic oxide. This doctrine has, however, been recently called in question by M. Dubrunfaut, who insisted that carbonic acid, when anhydrous, cannot be reduced to carbonic oxide by perfectly dry charcoal; and that in order to effect this reduction, either the carbonic oxide or the charcoal must contain water, as, according to him, the presence of aqueous vapour is absolutely essential in order to bring about this reaction, and that this is also the case when carbonic acid is reduced to carbonic oxide by metallic iron, or when carbonic acid is formed by the action of oxygen on charcoal; in all which reactions M. Dubrunfaut declares the effect of the aqueous vapour to be merely catalytic.

In consequence of these statements, the subject has very recently been investigated experimentally by Dr. J. Dumas, who has communicated an abstract of his results in the *Comptes Rendus de l'Académie des Sciences* for August 26th, in which the following conclusions are arrived at:—When absolutely dry, carbonic acid gas is passed over charcoal, entirely free from hydrogen, and heated to a cherry-red heat; this gas *is* converted into carbonic acid. Charcoal, even when strongly ignited in closed vessels, retains hydrogen or water energetically, which can only be eliminated by exposing the charcoal for a long time to a current of chlorine gas at a red heat. Charcoal not so treated with chlorine yields, when employed for the reduction of carbonic acid into carbonic oxide, a

gas contaminated with traces of hydrogen. When a slow current of dry carbonic acid gas is passed over metallic iron at a bright red heat, a portion of the carbonic acid is reduced to carbonic oxide—the bulk, however, remaining unaltered or undergoing regeneration.

Casarteli's Pyrometer.—This pyrometer, used for determining the heat of the hot blast, has been recently patented in England, and is described as follows:—The apparatus consists of a pipe or tube of iron or other material, which is screwed or fastened into a metal cone at one end, and to a flange or socket at the other end. Inside this pipe or tube is a second or smaller tube of metal or other material, the ratio of expansion of which by heat is different from that of the outer tube. This inner tube is also screwed or fastened at one end into the metal cone before mentioned, and at the other end has a rod screwed or fastened into it, which is made to pass through a stem screwed into a flange socket attached to the top of the main tube, and which said stem carries a case and dial. The rod being moved up or down, according to the expansion or contraction of the metal, comes in contact with a rack movement on the dial plate, and gives motion accordingly to the index hand. The hot blast is passed through the instrument by inserting the cone into the socket of the plug of the tuyere tube, the current passing through the inner tube or pipe through holes at its top between the inner and outer tube or pipe, and out through holes in the cone. By this means the heat of the blast elongates the pipes or tubes, and the temperature is indicated by the index hand on the dial plate. The outer tube of the apparatus has a covering of wood, or other non-conducting material, for the purpose of allowing its being handled comfortably, as well as to prevent the radiation of heat from the tube. The stem carrying the dial case is provided with an arrangement for adjusting or setting the index hand to zero when required.

Blast Furnace Construction.—The blast furnaces employed in smelting iron ores in Great Britain, beyond having been, from time to time, enlarged in size or internal capacity, remained without any great alteration in their external shape, or other improvement in construction, from the last century up to about the middle of the present one, being, during that period, little more than great pyramids of massive masonry surrounding a central cavity in which the smelting of the iron ores took place; many

examples of these are still to be seen in various parts of Scotland, Wales, and Staffordshire. The commencement of the iron manufacture in the Cleveland district, however, inaugurated quite a revolution in this respect, as well as in many other time-honoured details of our blast furnace practice; and furnaces were built which were but thin stacks or mere shells of brickwork, encased in an outer coating of plate iron, and under which the massive columns, or rather solid blocks, of brickwork or masonry, which formerly supported the body of the furnace, were replaced by cast-iron columns, which modification not only immensely reduced the quantity of materials required for the construction of the furnace itself, but also allowed of easy access to the region of the tuyeres and hearth of the furnace. On the Continent, however, the ironmasters were long in following the example shown by Cleveland; and to this day most of the iron furnaces are seen to be but copies of what the usual style of construction in England was before 1850. In 1865, however, it would appear that the first step in this direction was taken by M. Buttgenbach, the manager of the Neuss Iron Works, near Dusseldorf, in Rhenish Prussia, who introduced his new system of blast furnace construction, which, although evidently based on that of the modern English furnace, differs from it in several details. A model of his first furnace was placed in the Paris Exhibition of 1867, where it received the only prize in its class, and is now in the museum of the Ecole Centrale des Arts et Manufactures in that city. Since then, blast furnaces on this system have been erected at the Usines d'Anzin, near Valenciennes, at MM. de la Rochette's, and at MM. Harel & Cie.'s ironworks, near Lyons; at the St. Louis Works, near Marseilles; and in Austria, at Inneberg, near Vienna, and at Putten, whilst various others are now in course of construction in both France and Germany. Descriptions and figures of the furnace will be found in the Portfueille Economique for October, 1869; the Berg u. Huetten. Zeitung for 1870, p. 436; and still more recently, in Professor A. Kerpely's report, just published; and as this system is coming every day more into use on the Continent, as well as from its containing several features which may be found applicable to our own furnaces in England, we think it may not be out of place to direct attention to the mode of construction as now carried out.

The principle on which Herr Buttgenbach's system of con-

struction is based, is that the shaft of the furnace itself shall be as far as possible isolated and independent, either of the base below or the charging bridge above, in order that it may thus be enabled to expand and contract freely, without affecting the other parts of the structure; in order to effect this, the base of the furnace is formed of seven brickwork piers, disposed in a circle and inclining slightly inwards, their tops being connected by arches and by a crown ring, which rests in a recess formed in the inner side of the ring of brick-work on the top of the piers. The shaft which rests on this crown ring is built of one ring of fire-clay blocks, moulded to the proper form, and only eighteen inches in thickness. The boshes meet the stack as usual, and at their widest part are held in by the crown ring of the piers, both the stack and boshes being braced with iron hoops, and at their junction the boshes are protected by water boxes, which are likewise applied to the hearth and to the tuyeres and tymp arch. The top platform, bridge or charging gallery, as it is variously called, is not supported by and has no connection with the furnace shaft, but rests upon five hollow wrought iron columns, which spring from the top of the base, these columns serving as pipes for carrying down the gases from the furnace top into an annular reservoir, in which all the dust collects, and from which they are conducted to the boilers, air-heating stoves, &c. At first glance it would appear that such thin walls would be likely to give rise to a considerable loss of heat from the cooling action of the surrounding air, but the experience of seven years with two furnaces at the Neuss Iron Works, the one built on the old system of thick walls, and the other with walls only 18 inches thick, formed of only one ring of fire-brick, without any other surroundings, have afforded practical proof that the new system is the more economical in working as regards the consumption of fuel; whilst these walls have the advantage of being more durable, since repairs can be made at any time during the working without the least difficulty, and any part of the wall may be examined by boring a hole of say one inch diameter through the fire-brick, which affords the means of ascertaining, at any time or in any part of the shaft as to how far it may be worn away on its inside; this small hole being kept closed by a clay plug, put in from the outside. Owing to the cooling action of the external air, the shaft, which, as before stated, is only 18 inches thick, during the seven years which it has been

in use at the Neuss Works has not lost more than half-an-inch in thickness internally; it is braced every three feet with iron hoops, 3 inches wide and ½-inch thick, and has never shown any trace of gas escaping through its joints, whilst no damage or difficulty in re-commencing work was found when, in the commencement of this year, the furnace had to cease working during 62 days, on account of insufficient supply of coals. This furnace, which is 53 feet in height and 16 feet across the boshes, turns out nearly 50 tons fine-grained pig iron, rich in manganese, per day, with a consumption of from 20 to 22 cwts. of coke per ton of pig iron, and in cost of erection can be built for at least 25 per cent. cheaper than one of the same dimensions but of the ordinary construction. There is no cast iron used in the whole furnace, and the total weight of the hoops and braces does not amount to two tons. If the blocks of the shaft are to hand, such a furnace can be built within a month, and as no mortar is employed, the joints of the fire-bricks being only cemented by a thin mixture of clay and water, the entire drying and heating previous to blowing-in does not require longer than ten days.

Charcoal Blast Furnaces.—Under the title "Notes on a Charcoal Blast Furnace," by Mr. Charles A. Brinley, there has appeared in the *American Chemist* the results of the chemical examination of the ores, slags, and cast iron produced from the Richmond Iron Company's charcoal blast furnace, which is situated at Richmond, in Berkshire County, Massachusetts, U.S. This furnace is oval in shape, and 32 feet 10 inches in height, and full details are given as to its working; but as this paper has been re-produced in the *Engineer* of October 25, 1872, p. 285, we would refer to that journal for particulars.

Smelting Iron by Petroleum.—From the *New York Daily Bulletin* we learn that a joint stock company has been formed in Titusville, for the manufacture of pig iron, using petroleum in place of coal or coke, and that it is expected that the works will be in operation about New Year. At the present rate, the charcoal for making a ton of iron costs £3 8s. in the United States, whereas it is calculated that the mineral oil requisite for smelting this quantity of iron will not cost more than £1 8s., whilst, owing to the absence of sulphur and phosphorus in the oil, the iron made by it is expected to be of the best quality known in the market. The expenses of constructing the necessary works and appliances are

stated at one-half less with oil than with coal, and there will be a similar economy in labour and other charges. It is calculated that the refuse matter from the oil, which is now regarded as of scarcely any market value, will be quite as available for fuel as the crude oil itself. Petroleum is just as manageable as ordinary illuminating gas, and as safe; its force or heat can be diminished or increased at pleasure, and by the same process. The Lake Superior iron ores can be laid down at comparatively little cost almost at the mouth of the oil wells, and the new oil blast furnaces to be built at Titusville will be specially adapted for the required purpose, and the result will be looked for with general interest as involving the future of the iron trade of America. The article concludes by observing, "If successful, as it undoubtedly will be, if there are not very grave errors in the calculations of scientific men and experts, then the oil region will become the centre of a new industry."

Spiegeleisen.—The details of the manufacture of spiegeleisen, given by the foreign secretary in the first quarterly report for this year, have been translated into German, and have been published in Austria as well as in Germany, as will be seen by reference to the Oesterreichische Zeitschrift für Berg u. Huettenwesen and the Berg, u. Huettenman. Zeitung, No. 38, for July, 1872.

Iron Foundry.—A somewhat lengthy communication on the drying of the moulds used for casting iron, by W. Ledebur, will be found in No. 45 (November 8th, 1872) Berg und Huettenm Zeitung "Das Trochnen der Guss-formen in Eisengiesserein von A. Ledebur, in Groeditz," but as it is not well suited for condensation we cannot do more here than mention its title and refer to the original paper.

Malleable Cast Iron.—In the October (1872) number of the American journal of science and arts, we find a paper by Russell W. Davenport, Ph. B., entitled "Results of a chemical investigation of some points in the manufacture of Malleable Iron," and as the process employed in rendering iron castings malleable, or in other words converting them into wrought iron without changing their form, is one upon which but little is known in general, and still less published, it is thought that this communication might prove of sufficient interest to warrant a full account of it. "The annealing process employed in making malleable iron (or more correctly

malleable iron castings) consists, as is well known, in packing the castings with oxide of iron scale in cast iron chests, placing six or eight of these chests upon the hearth of a kiln or furnace, resembling a reverbatory furnace, and exposing them for five or six days to a bright red heat; the furnace is then allowed to cool, and the castings, as soon as they can be handled, are ready for finishing. The following analyses made of two samples about one quarter of an inch in thickness, each annealed twice, and analysed before and after each annealing, show what influence the process has upon the impurities contained in the iron. It will be seen that the iron employed was a fairly good charcoal iron; the unannealed castings, when broken, showed a white fracture, all the carbon being in the combined state, which last property must be possessed by all castings submitted to this treatment, in order to ensure the success of the process. The annealed castings, when broken, were up to the average toughness of "malleable iron," and the strength did not materially decrease after the second annealing.

I. Casting No. 1. Before Annealing.

	1.	2.	Average.
Silicon	·44	·45	·445
Phosphorus	·29	·34	·315
Manganese	·524	·534	·529
Sulphur	·064	·054	·059
Total Carbon	3·44	3·42	3·43

II. Casting No. 1. After First Annealing.

	1.	2.	Average.
Silicon	·440	·436	·438
Phosphorus	·323	·330	·327
Manganese	·57	·60	·585
Sulphur	·062	·072	·067
Total Carbon	1·53	1·49	1·51

III. Casting No. 1. After Second Annealing.

	1.	2.	Average.
Silicon	·447	·451	·449
Phosphorus	·31	·32	·315
Manganese	·51	·54	·525
Sulphur	·086	·081	·083
Total Carbon	Below 0·10 per cent.		

IV. Casting No. 2. Before Annealing

	1.	2.	Average.
Silicon	·59	·58	·585
Phosphorus	·29	·27	·280
Manganese	·55	·62	·585
Sulphur	·11	·10	·105
Total Carbon	3·50	3·43	3·48

V. Casting No. 2. After First Annealing.

	1.	2.	Average.
Silicon	·616	·612	·614
Phosphorus	·290	·291	·290
Manganese	·619	·613	·616
Sulphur...	·152	·141	·147
Total Carbon	·43	?	·43

VI. Casting No. 2. After Second Annealing.

	1.	2.	Average.
Silicon	·615	·613	·614
Phosphorus	·29	·30	·295
Manganese	·59	·56	·575
Sulphur	·161	·153	·162
Total Carbon	Below 0·10		

From the above analyses the following conclusions may be drawn: first, that the silicon, phosphorus, and manganese are in no way affected by the annealing process; second, that the sulphur is not diminished and may be slightly increased; and third, that the amount of carbon is reduced by each annealing, until finally only a trace remains. The slight increase of sulphur shown by both sets of analyses is probably due to the presence of that substance in the coal used as fuel. The castings before annealing containing $3\frac{1}{2}$ per cent. of combined carbon, showed, on breaking, a white fracture, and were too hard to be touched by a drill; after the first annealing an interesting change showed itself in the fracture; a whitish surface extended inwards for about one-sixteenth of an inch on all sides, surrounding a dark core of dull black colour; the line of change from the light to the dark was quite distinct and the whole could be pierced easily with a drill. A portion of this outside layer was filed off and the carbon determined only to be present in traces, while analyses II. and V. show the presence of a considerable amount of carbon when a sample of the entire iron section was taken.

The black core was noticeably smaller in the case of casting No. 2 than in that of casting No. 1, which accounts for the small amount of total carbon in analysis V. After the second annealing the black core had entirely disappeared in both cases, the whole fracture being of the same appearance as the white border mentioned before, the amount of carbon in a sample of the whole cross section as shown by the analysis was reduced to a trace. It would appear from the above that when a casting does not much exceed one-eighth of an inch in thickness, the carbon is approximately eliminated throughout the whole mass by the ordinary annealing process; when, however, the casting is thicker, the elimination only extends from the surface into the mass for a certain distance, but may be carried further in by a repetition of the process. It would also seem, that in the interior of a thick casting where the amount of carbon is at all events only partially reduced, that which remains is, by the high heat and subsequent slow cooling, changed in its state of occurrence from combined carbon to a species of uncombined or graphitic carbon; for where the iron before annealing is white and very hard, after annealing it shows a dark fracture and is quite soft. Its behaviour, too, with nitric acid would lead to the same conclusion, for whilst the white unannealed iron dissolved perfectly in that re-agent upon standing a few hours, and gave to the solution the same clear brown colour which is noticed when a high steel is so treated, the annealed "black heart," as it is technically called, gave a dirty green colour to the solution and a black carbonaceous residue remained.

The manufacturers of "malleable iron" are occasionally troubled by a lack of toughness in the annealed castings when these are exposed to a sudden blow or bending strain. This weakness is at times doubtless caused by the natural rottenness of the iron, owing to the presence of an excessive amount of silicon, phosphorus, or sulphur; but it also must frequently be due to a crystalline structure which the iron, under certain unknown conditions, assumes while being annealed. This structure shows itself in the fracture of an annealed casting in the form of bright crystalline faces which occasionally extend entirely across the fracture.

Further analyses were made of another specimen, before and after its annealing, which when annealed and broken was brittle, and showed the crystalline structure to some extent.

VII. Before Annealing.

	1.	2.	Average.
Silicon	·577	·580	·579
Phosphorus	·425	·423	·424
Manganese	·154	·117	·165
Sulphur	·116	·112	·114
Total carbon	3·277	3·285	3·281

VIII. After Annealing.

	1.	2.	Average.
Silicon	.560	?	·560
Phosphorus	.460	·440	·450
Manganese	·136	·158	·147
Sulphur	·113	?	·113
Total Carbon	below 0·10 per cent.		

The weakness in this case may perhaps be partially caused by the large amount of phosphorus present; but the next two analyses made of specimens, which, when broken up after being annealed, were very brittle and showed a most decided crystalline structure, go to prove that this phenomenon of crystallisation cannot be attributed to the presence of an excessive amount of silicon, phosphorus, or sulphur.

IX. Once Annealed; large crystalline faces in fracture.

	1.	2.	Average.
Silicon	·440	·460	·450
Phosphorus	·267	·266	·266
Manganese	·264	·182	·223
Sulphur	·145	·133	·139
Carbon	below 0·10 per cent.		

X. Twice Annealed; crystalline faces extended entirely across the fracture.

	1.	2.	Average.
Silicon	.585	·593	·589
Phosphorus	·213	·212	·212
Manganese	·149	·158	·153
Sulphur	·092	·118	·105
Carbon	none or slight trace.		

The above analyses seem to afford no explanation of this crystalline structure; and the cause of it can only be determined by carefully experimenting, and by the comparison of a large number of trustworthy analyses.*

The next analysis was made of an annealed casting, which when bent, showed a greater degree of toughness than common. It was of circular section, half-an inch in diameter, and was bent cold through an angle of 90 deg., without showing fracture.

XI.	1	2	Average.
Silicon ...	·717 ...	·722 ...	·719
Phosphorus ...	·206 ...	·202 ...	·204
Manganese ...	·273 ...	·268 ...	·270
Sulphur ...	·035 ...	·037 ...	.036
Total carbon ...	1·840 ...	1·844 ...	1·842

From this analysis it may be inferred that the silicon may run as high as 0·7 per cent. without affecting the toughness of the annealed product, whilst it also tends to show what might certainly be expected, that an iron low in phosphorus and sulphur is most suitable for making malleable iron. The author of this report would also remark that the amount of carbon present shows that the annealing in this case has not proceeded so far as to produce iron, but has been stopped when the metal was in the steel stage, which probably accounts for its superior tenacity when bent as described.

DEPHOSPHORISING IRON IN PUDDLING.—We understand that a patent has been applied for in this country for the process of Professor T. Scheerer, of Freiberg, which was briefly alluded to in our last report, and which consists in adding a mixture of equal quantities of chloride of calcium and common salt to the molten iron in the puddling furnace and then rabbling it in; as, however, the patent is not yet completed, we cannot communicate the details of its claims. Accounts of recent trials made of the process in Germany speak favourably of it, and state that the expense is in greater part covered by the shortening of the operation and the diminishing of the loss of iron.

* The author of this report would deduce from the figures given above, and from the fact that the carbon in IX. had been eliminated by a single annealing, that the brittleness of the specimens was in reality caused by the absorption of oxygen from the iron scale in which they were imbedded, which would be very likely to take place when the entire carbon had been removed. Probably the result was due to the samples having been kept too long in the furnace during the first annealing.

Mechanical Puddling.—A new system for applying steam power for working the rabble in puddling furnaces, the invention of a Mr. Alan Wood, of Conshohecken, in Pennsylvania, U.S., is said to greatly accelerate the operation and lighten the labour of the puddler; as yet, however, no details of the process have been received, and now that rotary furnaces have come into use, all such arrangements may be regarded as not up to date.

New Rotary Puddling Furnace.—According to the American Mining Record, a new rotary furnace, invented by a Mr. C. Donkersley, of the Morgan Iron Works, near Marquette, has, after experiments covering a space of about two years, at last been so far perfected as to have proved a complete success. This furnace is built with a combustion chamber about four feet square and thirty inches high, into which the fuel (slack and coal dust formerly wasted) is introduced in the form of fine powder by means of a No. 2 Sturtevant blower. In this chamber the fuel is entirely consumed, and the heated gases pass over an arch into the puddler, and therefrom to the chimney stack. The puddler is four feet in diameter and five feet long, lined with conglomerate, and fettled with iron ore. It revolves upon four bearings, one set under each quarter, and is driven from the principal engine of the works by means of a shaft and gearing working with toothed segments fixed around its circumference at either end. A chamber is placed between the puddler and the stack, which is raised at right angles with the axis of the puddler by a counterweight, thus affording access to the interior of the puddler. The charges are run in directly from the blast furnace, and half a ton ball is handled with great facility. The balls are at present bloomed under a powerful hammer, but it is contemplated to erect a Siemens' reheating furnace, and carry the stock to the rolls without losing its virgin heat.

Rolling Iron.—The memoir of Mr. Daelen on the construction of the grooves in rolls, to which the prize was awarded by the "Verein zur befoerderung des Gewerbfleisses in Preussen," has been translated into French, and will be found in the 3rd part (for May, 1872) of the Revue Universelle des Mines, &c.

The system of rolling invented by M. H. Vigour, of Ardennes, in France, has been recently patented in England, and is described as certain improvements whereby iron bars, having both round and

square parts or other different sections, shall necessarily be rolled of exactly equal diameter in both the round and square parts or other sections. These improvements consist in placing, immediately behind two horizontal cylinders grooved partly round and partly square, or other varied section, two vertical cylinders having exactly similar grooves, and in placing between the horizontal cylinders and the vertical cylinders a continuous guide, which takes the iron as it issues from the horizontal cylinders, and leads it into the vertical cylinders.

INFLUENCE OF MAGNETISM ON STEEL.—In October, an account of certain experimental investigations made by MM. Tréve and Chédeville, to ascertain whether the influence of magnetism changes in any way the internal structure and powers of resistance of cast steel, was communicated to the Academy of Sciences at Paris. In these experiments two cylindrical moulds precisely similar one to another were filled with molten cast steel, one of which was, during the entire period of the cooling of the steel, surrounded by a coil (made by Ruhmkorf), through which the current from a 12-element Bunsen's galvanic battery was passed, whilst the other was allowed to cool as usual. At the expiration of ten hours the two steel cylinders were taken out, and each broken in several fragments in order to examine their internal structure, when it was found that the grain of the metal differed considerably in appearance in the two castings, the grain being visibly finer in that subjected to magnetic influence during cooling, which was found to be the case also in three instances in which this experiment was repeated. Comparative experiments were then made by M. Chédeville as to the resisting power of the two steel castings to extension and compression, the results of which indicated that the magnetised steel offered in every instance less resistance than the other.

TUNGSTEN STEEL.—Chemical analyses of Mushet's so-called "special" steel, which is remarkable for its hardness and strength, have been made by a chemist in Hanover named Heeren, who has published his results, and finds it to be merely tungsten steel containing 8·73 per cent. of tungsten along with 1·73 per cent. of manganese. This class of steel is manufactured in Germany at the works of Messrs. Wund and Co., at Buckaw, near Magdeburg, in Prussia, and in Hanover at Uslar on Solling, and the magnets used

by Messrs. Siemens's telegraphic works in Berlin are also made at Moabit of this steel. Its qualities are very different from those of ordinary steel, as although when annealed it is so hard as to resist the best files, it becomes soft when chilled, and presents an exterior full of cracks, for which reasons it must not be hardened. At a red heat it is malleable and easily worked, but all tools made of it must be brought into shape by the hammer at once, and finished if necessary under the grindstone, as the file will not touch it afterwards. Tools of tungsten steel in use for planing and other machines at the Engine Works of Messrs. Knoevenagel, in Hanover, are reported to stand longer than those made of the best Sheffield cast steel.

In Kicks techn. Bl. Heft 2, p. 122, 1872, it is stated that a steel analysed by Messrs. Mueller and Kick, which contained 8·777 per cent. tungsten, 2·527 manganese, 0·759 silicon, 0·009 phosphorus, 80·01 sulphur, and 0·405 titanium, was not found to be of good quality.

A species of steel invented by Mr. H. A. Levallois, of Paris, has lately been patented in England (August 10, 1872, No. 2,389), which is stated to be an alloy containing tungsten and nickel in various proportions, and claimed to be less liable to oxidis or rust than ordinary steel.

The Barron Steel Process.—Under this designation a system of converting articles of cast-iron into steel has been, during the last few months, carried out practically, and it is stated successfully, in the United States; the conversion being effected with great rapidity, each charge of about one ton of iron castings not requiring, according to the account sent us, more than from eight to ten minutes in the operation. The description received is very vague, and, according to it, the articles such as work tools of all kinds are cast in sand, as usual, and then placed in revolving drums, by which the hard outer surface or scale of the castings is worn off, and the castings themselves polished by the attrition. They are then subjected to the action of oxide of iron, or other decarburizing agent, by being packed in layers in iron boxes closely covered with clay, in which they remain for from three to six days, whereby they are converted into iron, as in the usual process for making malleable castings. They are now re-converted into steel by exposing them in a large retort to the action of certain gaseous

compounds of carbon, the nature of which we have yet to learn, since as yet they have not been specified.

THEORY OF THE BESSEMER PROCESS.—In opposition to the deductions which Kupelweiser and Snelus have drawn from their chemical analyses, Kessler finds that in the Bessemer process of steel-making, the entire amount of carbon present (owing to the oxidation of the other substances being, in the commencement of the "blow," more energetic) increases relatively, as in puddling, and that the carbon first begins to oxidize after the major part of the silicon has disappeared. The amount of phosphorus in the steel decreases in the middle stage of the process, but increases both in the commencement of the "blow"—owing to the relative greater oxidation of the other substances—as well as at the end, when it is, in part at least, taken up again from the slag. Sulphur decreases rapidly at first, but then increases in the middle stage, up to the addition of the spiegeleisen, for the reason that a portion of it, which in the first stage went into the slag in the form of metallic sulphides, was afterwards again taken up by the iron. So long as the manganese is being oxidised and removed from the iron, the percentage of sulphur in the iron diminishes; but as soon as the iron is free from manganese, it again takes up a portion of the sulphur contained in the slag. When the spiegeleisen is added, and the "blow" recommenced, the sulphur again diminishes; and if the first slag (which is sulphurous) could be removed, then it would be possible to use brands of iron which are known to contain sulphur for making Bessemer steel.

BESSEMER MACHINERY.—A lecture on this subject, by Mr. Alex. L. Holley, which was recently delivered before the students of the Stevens Institute of Technology, gives a very good sketch of the Bessemer system of steel-making as at present carried out in the United States of America. It has, however, been reproduced, with illustrations, in the number of *Engineering* for November 22, and to this periodical we think it better to refer for its substance.

A short paper, by M. Bleichsteiner, of Gratz, which is published in the Revue Universelle des Mines, &c., 1872, vol. xxxi., p. 275, entitled, "Note sur les nouvelles installations Bessemer," treats of the arrangements and character of the Bessemer machinery in the newer establishments on the Continent, and is illustrated by a plate.

AMOUNT OF MANGANESE IN DIFFERENT STEELS.—Kessler, in Dingler's Polytic. Journal, vol. 205, p. 43, gives the results of the determination of the quantity of manganese in the following varieties of steel :—

Krupp's crucible cast steel, Essen ...	0·437 to 0·438 p. cent.
Bochum cast steel	0·312 to 0·317 „
Hasper steel	0·327 to 0·332 „
Hoerder steel	0·167 to 0·170 „
Manganese steel of Ludvig, in Berlin	0·303 with 0·31 silicon.
Fine pianoforte wire	0·035 „

COLORIMETRIC DETERMINATION OF COMBINED CARBON IN STEEL.—A paper on this subject, by Mr. J. Blodget-Britton, is published in the Journal of the Franklin Institute for this year; but as it has already been reproduced in the Chemical News for September 20th, 1872, we must refer to that journal for details.

ESTIMATION OF MANGANESE IN IRON AND STEEL.—Kessler has investigated the separation of iron from manganese effected by the use of acetate of sodium and boiling, and finds the process to be defective in proportion to the quantity of acetate of sodium employed. Direct experiments gave the following numbers when 300 cubic centm. of liquid was used along with 15 grammes of acetate of sodium, without any free acetic acid :—

Actual percentage of manganese present,	1·00	3·00	7·00	13·00
Loss of manganese in percentage, ...	0·21	0·60	0·87	1·06

If, however, the solution of the iron be treated as follows, 1 gramme of acetate of sodium is sufficient to precipitate completely 1·1 gramme of iron from 500 cubic centm. of solution; and this precipitate carries down with it only from 0·02 to 0·05 per cent. of manganese, even if the iron solution contain as much as 13 per cent. of manganese, so that in such case the error is so small that it may be overlooked. The hydrochloric solution of chloride of iron is neutralised with carbonate of sodium until a permanent precipitate is formed, and then hydrochloric acid is added cautiously until the precipitate is just redissolved. The liquor then contains fourteen-fifteenths of the iron dissolved as hydrate in the chloride of iron solution, this hydrate not being separated by boiling. The acetate is then added, and the whole boiled a few minutes.

To avoid washing, Kessler then dilutes the cooled liquid with the precipitate to a known bulk 500 cubic centm., and filters off

one-half through a dried filter; the error thus produced being so minute that it can be overlooked. To estimate the manganese, 10 grammes of acetate of sodium are dissolved in 50 c.c. of water; 50 c.c. of Bromine water are then added, and then the manganese solution is added in portions of 50 c.c. each every half-hour, another 50 c.c. of Bromine water being added after the third addition of manganese. Almost every trace of manganese is thus thrown down as di-oxide, and can be estimated by adding hydrochloric acid and a known antimony solution, and then titrating by a standard permanganate solution. If cobalt is present, a slight error is introduced, as this metal is also thrown down (as a sesquioxide) by the Bromine water. Copper and nickel are precipitated as non-oxides.

Another and quite different process for separating iron from manganese is communicated by M. J. P. de Rezende in the Annales des Mines, 1872, 7th series, vol. i., p. 418, and is based upon the fact that the oxide of iron, in a solution of sesquichloride of iron, is precipitated completely by prolonged boiling with black oxide of copper, whilst the chloride of manganese remains unaffected. A solution of the two metals in hydrochloric acid is, therefore, first peroxidised by chlorine, and after all excess of that gas has been expelled by boiling, is treated with an excess of the black oxide of copper (prepared by calcining nitrate of copper), boiling the whole continuously for some five or six hours; after which the precipitate is washed first by decantation, and afterwards with boiling water on the filter, until the wash waters are no longer discoloured by sulphide of ammonium. The solution, which then contains the manganese along with copper, is treated first with a current of sulphuretted hydrogen gas, and after the separation of the sulphide of copper the manganese in the filtrate is precipitated by sulphide of ammonium, and determined as usual. The precipitate containing the iron is separated as far as possible from the filter, which is incinerated, and its ashes added to the precipitate, and the whole dissolved in hydrochloric acid diluted with water, and treated with a current of sulphuretted hydrogen gas until all the copper has been precipitated. The sulphide of copper is then separated by filtration, and the filrate, after being boiled to expel the excess of sulphuretted hydrogen gas, and filtered from any precipitated sulphur, is preoxidised, and the iron precipitated by ammonia, and determined in the form of sesquioxide as usual.

This separation is stated by its author to be very exact when the proper precautions have been taken. Amongst these must be mentioned (1) that a sufficient excess of the oxide of copper is employed, and experiments have shown that from eight to ten parts of oxide of copper should be used to each one part of iron contained in the solution. (2) That the boiling has been carried on sufficiently long. There is an inconvenience attendant on this, as the long boiling brings the oxide of iron into so fine a state of division as to render it very liable to pass through the filter. It is therefore best to wash by decantation, using boiling water some three times before placing it on the filter. (3) That the oxide of copper be prepared by calcining the nitrate of copper, as oxide precipitated by potash always retains traces of the alkali, which might risk the precipitation of some of the manganese along with the iron.

ESTIMATION OF PHOSPHORUS.—L. Brunner, in the Zeitschr. Analyt. Chemie, xl., p. 30-32, recommends where phosphoric acid is determined by precipitation with ammonia-magnesian sulphate, that it should always be effected in the cold, and cites an experiment where, when equal portions of the same hydrochlorid acid solution of phosphate of lime were precipitated, the one at 68° and the other 150° Fahrenheit, it was found that the former was correct, but that the latter afforded a result corresponding to 1·25 per cent. more phosphoric acid than actually present in the solution.

ESTIMATION OF SULPHUR IN COAL.—A paper on this subject, by G. W. Mixter, will be found in the American Journal for science and arts, Ser. iii., vol. iv., p. 90, 1872. The author gives full details of his process, illustrated by a woodcut of the apparatus, for determining the sulphur present in coal (or other organic substance) he burns the coal in a confined volume of oxygen gas, and condenses the gaseous products, in which the sulphur is present in the form of sulphuric acid, in water containing a little bromine, from which solution the sulphuric acid is afterwards precipitated by a salt of Barium, and determined as usual as sulphate of Barium.

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DR. WEDDING ON THE WORKING OF BLAST FURNACES WITH RAW COAL AT GLEIWITZ, IN UPPER SILESIA.

[TRANSLATED FROM THE GERMAN, BY MR. ERNEST BELL.]

COAL was used in the blast furnace before coke came into use. In England, the earliest experiments, mostly unsuccessful however, to substitute mineral fuel for charcoal, were made by Dud Dudley in 1620, and after many years, when the results of the former experiments were almost forgotten, by Abraham Darby, in 1730. Coal, in some cases alone, in others mixed with coke, was not employed with promising results in the blast furnace till after the introduction of the hot blast; first in Scotland in 1830, then in South Wales and South Staffordshire, and in 1840 in North America. About this time, a few unconnected experiments with the same object in view were made on the Continent, in France at Decazeville, in Upper Silesia at Konigshütte, between the years 1835 and 1837. On the blowing in of the "Wedding" furnace at the latter works in 1835, after good results had been obtained from using raw coal, endeavours were made to increase the profits by using this fuel, resulting, however, in the discovery that the temperature in the furnace decreased, instead of increased, as was expected. In the year 1835, with a mixture by volume of $\frac{1}{3}$ coal and $\frac{2}{3}$ coke, better results were obtained; but nevertheless, so many difficulties, such as the irregular descent of the furnace charges, had to be encountered, that after a final endeavour in 1837, the attempts to use coal were again abandoned. The next experiments on a large scale, passing over the failures at Friedrichshütte in 1857 and 1858, took place in 1852 at Königshütte. These, conducted by Herr Erbreich, and described at length by him in XI. Vol. of these Transactions, showed, however, in spite of the great care and forethought with which they were conducted, at the stage when they were suspended, no particularly promising results. The number of charges per day when working with coal alone decreased about 20 to 25 per cent., and, indeed, after three or four weeks, 50 per cent. In the well of the furnace the metal and slag were at a remarkably low temperature. The metal was solid in fracture, mottled, and at the edge white, showed little strength, was with difficulty melted in the puddling furnace, but soon balled, and yielded undurable short-fibred

malleable iron, containing little carbon, with a very high percentage of silica. After working four weeks, it became necessary again to use coke, owing to the hearth growing up and the furnace scaffolding. Even an increase in the temperature of the blast (from 250 to 330 degs. C) did not improve the working of the furnace. The burden in the blast furnace consisted of calcined clay-ironstone, mill cinder, and limestone. The furnace was of the following dimensions :—Height, 15·22 metres; width at throat, 2·59 metres; bosh, 4·65 metres; and at the level of the tuyeres, 6 in number, 1·26 metres. In a second series of experiments, the fuel consisted of, by volume, one-half of coal. At first, the burden was calcined brown hematite with raw limestone, and afterwards raw hematite with burned limestone. With this burden, although the working condition of the furnace was good, the production decreased, the quantity of fuel consumed was greater, and consequently the cost price of the metal, which had deteriorated in quality, was higher.

According to these results, it was inferred: That the brown hematite of Upper Silesia could not be smelted either with raw coal alone or with a mixture of coal and coke in equal proportions: That even a much less proportion of coal than one-half would, in all probability, be inadmissible: That the cause of failure was possibly due to the poverty and decomposed state of the ore, which differs from that of England, where raw coal is successfully used: That the use of raw coal, instead of coke obtained from the same coal, changed the condition of the furnace by virtue of the cooling effect of the operation of coking, which, when the fuel is used raw, goes on in the furnace itself.

The conclusions were evidently too sweeping, although the explanation of the failure of the experiments must be regarded as correct. This erroneous conclusion finds an explanation in the untenableness of the theory by which it was sought to connect the cause and effect. It was assumed that in every blast furnace there existed two distinct zones, being characterised by prevalence, in the upper one of carbonic oxide, in the lower of carbonic acid, and that the working of the furnace depended principally on the relative space occupied by these two zones. Since that time, however, it has been satisfactorily proved that the quantity of carbonic acid gas in the blast furnace gases at the tuyeres is, under all circumstances, very small, therefore the question of a great height of zone of carbonic acid gas cannot exist; that the quantity

of carbonic acid gas near the tuyeres is dependent on conditions (temperature of blast, strength of blast, &c., &c.) existing outside the furnace. If we substitute, therefore, "reducing" and "melting" for "carbonic oxide" zones, and look for their difference in the difference of the temperatures of their respective gases, the foregoing may be regarded as correct.

The difference which is apparent in working a blast furnace with coal, and the same furnace with coke manufactured from precisely similar coal, the rest of the burden in both cases being the same, is easy of explanation. In the first case, the volatile substances are driven out of the coal in the furnace; while in the latter case, it is done in the process of coking outside the furnace.

The combustible part of the fuel, by the time it comes opposite the tuyeres, differs in either case but slightly. Small differences may exist in the possibility of diminishing the quantity of sulphur (in coke already diminished about one-half by its being cooled with water) by evaporation in the reducing atmosphere of the furnace; also, in the greater density of coke made under pressure in the furnace. The escaping gases are not different when using coal. The causes of the difference in the results obtained when working with raw coal are—Firstly, that heat is consumed in the process of coking, and, therefore, lost to the zone in which the process takes place, which is not the case when using coke; secondly, that the coal, and also the gases generated during the process of coking, occupy a greater space. These two causes tend to diminish the temperature in that part of the furnace where the coking takes place, and indirectly, therefore, reduce the temperature of the whole. The heat which is lost in these ways can be tolerably accurately determined by comparing the quantity of escaping gases when using coal, with the quantity when using a corresponding quantity of coke. In other words, we regain the heat lost when using coal by utilising the escaping gases. This loss of heat in the furnace explains the phenomena and results of the experiments carried out at Königshütte and elsewhere. As regards the quantity of fuel, a complete saving when using raw coal can only be effected by preventing the loss of carbon arising from an imperfect method of coking (such as, for example, open clamps, heaps, &c., &c.), and the loss arising from drawing and transporting the coke. As regards other circum-

stances which tend to reduce the temperature, first, that coal will have the least cooling effect which absorbs least heat before it arrives at the burning point, therefore, the least gaseous; and, secondly, the cooling effect will be more apparent the greater the proportion of the ores and flux to the coal. The poorer the ores the more flux they require.

This loss of heat will be apparent by the delay in the reduction, and if not remedied, by the imperfect reduction of the ores in the higher part of the furnace, by the presence of unreduced ore in the melting zone, by the consumption of carbon for reduction in the melting zone, and, at the same time, by a greater and greater loss of heat, resulting in dull iron containing large quantities of silicates and carbon, and ending in the furnace being gobbed up and entirely losing heat.

It has not been said, however, that these difficulties cannot with proper arrangements be overcome, even in cases where many unfavourable circumstances are combined, where the coal is very gaseous and the ores poor, and require much flux. A remedy in such cases lies in the shape of the furnace. To this circumstance, which has already been impressed upon you by the author in 1861, enough attention is not always paid. That which was wanting in the old furnace has been carried out in the new construction. In the first place, a well of a greater diameter is necessary, in order that by increasing the number of tuyeres, a corresponding combustion of carbon in a unit of time may result, and in consequence of this a proportionate decrease of radiation and an increase of production, and a higher temperature. The temperature cannot be increased, as is the case when using coke, by the simple addition of more fuel in proportion to the quantity of ore, because the greater the charge of fuel the greater the loss of heat by coking. Hot blast is requisite, owing to the greater density of the coke produced. With these exceptions, no other arrangements are necessary, other than those required when working with coke. If we proceed without changing the diameter of the well and the pressure of the blast, and use instead of cold, hot blast, we not only do not gain, but lose, because the volume of oxygen per unit of time going into the furnace is reduced. Further, wide throats are necessary in furnaces using coal, in order to lessen the velocity of the falling material, and of the escaping gases in the upper and

middle parts of the furnace. Calcining the limestone, and in particular instances the ores, will materially prevent loss of heat, because the heat consumed to effect this in the furnace will be more advantageously utilised. Hereafter, we may take for granted, that by a proper construction of furnace, coke may under all circumstances be superseded by coal; but whether this change is advantageous, and therefore economical, depends upon the circumstances of each individual case. Coking coal must, however, from the first be discarded. 1st. Owing to the trouble caused by large pieces of coke being formed in the furnace; and 2nd, owing to the ease with which small coal, which is injurious when used in a raw state, can be coked. On the other hand, no bituminous coal, which as small coal is not advantageously converted into coke, is in its raw state, when found in the neighbourhood, the proper material for working the furnaces.

It is, therefore, somewhat easy to foresee that in the course of time, in the blast furnace district of Upper Silesia for instance, where the main supply of fuel is non-bituminous, it must be consumed in a raw state in the blast furnaces, and if this should not altogether succeed, then from the small coal a suitable coke must be manufactured, which necessitates coke ovens constructed for the purpose. The failures of the experiments of Herr Erbreich must not daunt, but, on the other hand, give encouragement to make use of the knowledge already gained in carrying out new experiments on a more judicious plan. At works where the coke and coal have to be bought at a distance, and where a choice has to be made between the two materials, and often between different qualities of them, the question what fuel is most economical is much more important; because it is materially influenced by many circumstances which would otherwise not be considered, for example, the cost of transport. The works at Gleiwitz find themselves placed in the latter predicament; there, as will be proved further on, the price of the various fuels, bituminous coal, non-bituminous coal, and the coke made from each, did not differ materially. Under these circumstances, therefore, the task of reducing the cost of metal by using raw coal was a difficult as well as a desirable one. It was entrusted to Herr Wiebmer, who is well known for his report of his visit to England, and his researches on the hot-blast.

Before the beginning of the experiments detailed in this paper, working with raw coal was already recommenced at Antonienhütte, in Upper Silesia; and with an addition of coke, good results were obtained. With acknowledged promptness, the managers of these works communicated the results of the experiments to Herr Wiebmer, and with their co-operation the results were obtained at Gleiwitz. The results at both places show that an addition of coal is advantageous.

In the year 1869, two furnaces, Nos. I. and IV., were worked at Antonienhütte, to determine the difference of management when working with coke and with coal. No. I. furnace was worked entirely with coke; in contrast, No. IV. was worked the greater part of the time with the highest, and what was then thought the most advantageous addition of coal, viz., two-thirds by volume, and for a short time partly with coke alone, same as No. I., and partly with coal alone.

The results obtained from using coke alone were, it is true, very good; but the economical aspect, as compared with the results when using an addition of raw coal, was not so favourable, the latter being much cheaper. On the other hand, the three weeks' trial with raw coal did not give satisfaction, although endeavours were made to maintain the temperature by using burned limestone. In spite of this, the furnace cooled so considerably that the daily charges decreased about 30 to 50 per cent., causing deposits on the sides and bottom of the well. The cost price of the metal was very high, and the quality inferior.

In order to prevent the furnace going out, and to raise it to a heat at which it would work, it was necessary to charge for some length of time with coke.

The results were similar if raw limestone was used when working with two-thirds by volume of coal.

From these results it was now seen that one of the operations necessary to make the experiments with raw coal at Antonienhütte successful, was burning the limestone before putting it into the furnace, although it increased the cost of the flux four lbs. per centner of metal. On the other hand, preparing and calcining the ores had to be abandoned, because the expense was so great as to preclude the possibility of an economical advantage.

It was ascertained at Antonienhütte, as at Königshütte in 1862,

that, when working with raw coal, no higher pressure of blast is required than when working with coke made from that coal.

For some time it was the impression, that to consume coke made under a great pressure in the furnace, a higher pressure of blast was necessary; and therefore the pressure was raised to four lbs., but with unfavourable results, however. On reducing it to the usual pressure—viz., three lbs. per square inch—the furnace worked satisfactorily. During the time No. IV. was being worked with coal, the blast entered through eight tuyeres, each three inches diameter.

It is supposed that having numerous tuyeres, of small diameter compared to those used when working with coke, add materially to the success of the experiments when using raw coal. Although it has always been affirmed that a high temperature of blast is necessary to work with raw coal, it was nevertheless found that from 240° to 300° (C) were sufficient, and this was mentioned because any increase was found to deteriorate the quality of the metal. It was ascertained that No. IV. furnace worked better with raw coal, owing to its increased width consequent on its age, while with No. I., which had a new and comparatively narrow well, the experiments were not so satisfactory. A very wide throat was not found to be absolutely necessary. No. IV. had a well of 7 feet in diameter, and a throat 9 feet. No. II., which was blown in at Antonienhütte in 1870, is of the following dimensions:—Height, 13·15 meters; width of throat, 4·71 meters; of bosh, 5·65 metres, and has 8 tuyeres in the plane of the well, which is 2·35 metres in diameter. From this furnace, with a mixture of $\frac{2}{3}$ coal and $\frac{1}{3}$ coke with burned limestone, good results as regards fuel consumed were obtained. From this it would appear that a wide throat is advantageous when using coal. This furnace, however, has not worked successfully with raw coal alone. The addition of coal has not deteriorated the quality of the metal, a fact which has been proved by frequent chemical analyses.

This metal, when mixed with metal made with coke, works well in the puddling furnace, and on this account is in great demand.

No difficulty was experienced at Antonienhütte, with the above stated quantity of coal, in obtaining, when the furnaces were in good working order, different qualities of metal, such as No. 1, foundry, and forge. Indeed, the furnace has been driven for

a considerable time with the smallest possible quantity of fuel, and a white metal has been the result, which is used at many puddling works in preference, because it soon balls.

It is of much greater importance to Antonienhütte, that coal should be used in its raw state in the furnace, because their coal is so non-bituminous that only the large pieces can be used in coking; besides, the loss in coking is very great and the coke brittle, and soon falls into small pieces, and therefore will only bear a small weight in the furnace.

Although the quantity of fuel consumed, when working with a mixture of coal, is just as large as when working with coke alone, there is still a saving, in spite of the extra flux required, owing to the low price of coal compared to coke.

The similarity of the results at Antonienhütte and Gleiwitz cannot be doubted, more particularly because lately the coke at Antonienhütte was not made from non-bituminous coal, but from coking coal from the Königin-Louise pit; besides, this coke is, notwithstanding the high dues, much cheaper and better than the coke used at Gleiwitz.

However, there is a very important difference between the use of coal at the two places, viz., the price of large coal at Gleiwitz is much higher than at Antonienhütte, and therefore an equal saving was not to be expected.

On the other hand, another circumstance had to be considered at Gleiwitz, which, but for the fact that no direct economical advantage was expected, would by its importance have helped to rectify the protracted attempts in this direction. Lately, by using unclean water in the boilers, they became so encrusted that the furnace gases would no longer both raise steam and heat the blast. It was, therefore, not improbable that, by using even a small quantity of coal in the furnace, firing the boilers with small coal would be unnecessary, and thus a saving be effected.

The experiment was carried on in June, July, and August, 1870, at the Karsten furnace. The results are shown in the accompanying table.

In this experiment large coal from the König pit was used, because it was cheaper than coal from the Königin-Louise pit, which would not bear carriage better than coke. Also, the coke

made from it will carry a much greater burden than coke made from the Zabrzer coal.

The ore used throughout was brown hematite from the Perschtry mine at Tarnowitz. The use of clay ironstone was, owing to its high price at Gleiwitz, out of the question. Neither were the ores calcined, because the large outlay necessary for the plant, it was feared, would materially diminish the profits. On the other hand, for several rounds burned limestone was used. The existing kilns were not sufficient; it was therefore necessary to burn the limestone in clamps. This mode is not to be recommended unless fuel is very cheap, and not even then, because in wet weather, which was the case at Gleiwitz, the burned limestone is reduced to a powdered hydrate by the action of the rain, and thus rendered useless for the blast furnace.

I may here remark that two furnaces such as those at Gleiwitz require four lime-kilns, which would cost 8,000 thlr. to erect.

From the accompanying table it will be seen that one ctr. burned limestone costs 4 sgr. 7 pf.; therefore, by using it, the cost price of metal was increased 1 sgr. per ctr.; while at Autonienhütte, where fuel is cheaper, and where less loss occurred, the cost of production was only increased 4 pf. per ctr.

The following are the dimensions of the Karsten furnace, in which the experiments were made, it being considered the best adapted:—Height, 15·06 metres; width of throat, 2·35 metres; of bosh, 4·39 metres; and with eight tuyeres in the tuyere plane, which was 2·20 metres in diameter. These dimensions are very much the same as those of No. IV. furnace at Antonienhütte, which has, however, a somewhat wider throat.

In conclusion, I may remark as follows on the experiments stated in the accompanying table.

For the sake of comparison, I have placed those experiments first in which most charges were consumed. The metal made was mostly a large crystalled foundry, well adapted for such ordinary castings as do not require to be worked up, because, after being melted in the cupola furnace, it becomes too dense in the skin.

1st Exp. Fuel consisted of $\frac{11}{12}$ coke and $\frac{1}{12}$ raw coal; flux, raw limestone. After a few rounds, an unusual stream of gas was noticed in the boiler flues. By the time the rounds descended to the well, the furnace was doing such good work that the amount

of ore was increased 15 lbs. per round, without lessening the work of the furnace. The metal made was large crystalled, and flowed somewhat faster than that made with coke; otherwise it was very similar.

2nd Exp. Fuel consisted of $\frac{5}{6}$ coke and $\frac{1}{6}$ raw coal; flux of raw limestone. The larger addition of raw coal was beneficial. The heat increased in the well, the rounds were more frequent, and the slag very hot. Without increasing the temperature of blast, the quantity of ore was increased 25 lbs. per round. At the same time, the quantity of flux was diminished. These improvements were attributed to the greater purity of the coal from the König pit, compared to the Zabrzer coke. The quantity of gas given off was so great that firing the boilers and heating stoves was no longer necessary, and a saving of 12 tons per day of small coal was effected. The metal was large-grained, and better than that with coke, because it was more fluid; and after being melted in the cupola furnace, was soft and capable of being worked up.

3rd Exp. Fuel again $\frac{5}{6}$ coke and $\frac{1}{6}$ coal; flux, burned limestone. No effect was produced by using burned limestone during three days' trial. The results were very similar to those of the 2nd experiment.

4th Exp. Fuel, $\frac{2}{3}$ coke and $\frac{1}{3}$ raw coal; flux, raw limestone. The furnace had to be charged slower, and the quantity of ore per round in Nos. 2 and 3 experiments had to be reduced, in order to drive the furnace regularly. The quantity of gas given off increased. This, however, was no gain, because the gases given off in the former experiments, when only a small addition of coal was being made, more than sufficed to raise steam and heat the blast. The tension of the gases at the throat of the furnace became so great that the safety chimney had to be opened.

5th Exp. Fuel, $\frac{2}{3}$ coke and $\frac{1}{3}$ coal; flux, burned limestone. Burned limestone lessened the temperature in the well, and slightly reduced the number of rounds and the yield.

The metal was large crystalled, and resembled coke-made metal; it was, however, still adapted to foundry purposes.

6th Exp. Fuel, $\frac{1}{3}$ coke and $\frac{2}{3}$ coal; flux, raw limestone. The addition of a large quantity of coal soon made itself apparent. Compared to the former experiments, the charges were fewer, and the slag became tough. On tapping the furnace, the metal flowed

sluggishly, and was fine-grained. By lessening the burden of ore and increasing the temperature of blast as much as possible, endeavours were made to prevent the furnace losing heat; but, however, not with success till the

7th Exp., when burned limestone was used, without, however, changing the other quantities of material in the round. This, again, put the furnace in good working order, and the metal was large-grained and very strong.

The fine crystalled metal obtained from the two last experiments was tried at the puddling works at Herminenhütte, and was pronounced of inferior quality; because, owing to great waste in the puddling furnace, the yield was small and of poor quality.

8th Exp. In this experiment burned limestone was used with the raw coal, owing to it having proved itself the most advantageous. The results were quite the same as those obtained under similar circumstances at Antonienhütte and Königshütte; therefore, after three days, in order to increase the temperature and get the furnace in good working order, the burden was changed to that used in the second experiment. The metal made before the furnace lost heat was large crystalled, and could be used in the foundry; but that made during the latter part of the experiment, when the furnace had lost heat, was mottled. It proved unsuitable for puddling. The experiments have proved that, in order to obtain regular work and good yield, such as is obtained when using coke alone, not more than $\frac{1}{3}$ by volume of coal, such as that from the König pit, dare be used in working the furnaces at Gleiwitz. That the reason why a larger addition of coal may be made with advantage at Antonienhütte is, that there coal is less gaseous than that from the König pit, and, consequently, the loss of heat through coking in the furnace is not so great.

The greater width of throat at Antonienhütte had no doubt also a slight influence; at least the great pressure of gas in the narrow throat at Gleiwitz seems to make this suggestion.

The economical results, by far the most important results of the experiments, confirm what was expected, that notwithstanding the high price of coal, a saving as compared to working with coke alone would be effected in Nos. 1 and 2 experiments, while a larger addition of coal would increase the cost of production.

The saving was effected in Nos. 1 and 2 experiments, through

—1st, less coal and limestone being necessary in the furnace; and, 2nd, through almost no small coal being required to fire the boilers and heat the blast.

The fact, that according as the addition of coal increased, the burden consumed did not, but on the contrary decreased, is thus explained: The raw coal, which ought to bear a great burden, has its power to do so more than counterbalanced by the cooling effect in the furnace. On that account, a wide throat necessitates the ore being calcined, in order to balance this loss of heat. It was proved, however, that this did not give an economical result.

The satisfactory results of the second experiment have given encouragement henceforth to charge the Karsten furnace with $\frac{1}{6}$ coal and $\frac{5}{6}$ coke, which has thus far given satisfaction; but any attempt to increase the addition of coal has always resulted unsatisfactorily. Fine-grained metal made with this mixture of $\frac{5}{6}$ coke and $\frac{1}{6}$ coal is at present being puddled at Herminen-hütte, and gives good results. It works regularly, balls neither too fast nor too slowly, and gives, when used alone, faultless merchant iron and at the same time only moderate waste.

In order fully to understand the working of raw coal when white iron was being made, No 2 furnace at Gleiwitz (Schultz furnace) was experimented upon with $\frac{5}{6}$ coke and $\frac{1}{6}$ coal. Here a higher burden of ore was proved to be practicable; it was difficult, however, to make white metal when the furnace was in good working order; it was mostly mottled, and when the burden of ore was increased, in order to ensure a make of white metal, the furnace got out of proper working order. The quality of metal made on this occasion is not in great demand. White iron finds a ready market, and commands a better price than fine-grained grey pig iron. Therefore, so long as these circumstances exist, the Schultz furnace will be more advantageously worked exclusively with coke.

AW COAL AT

Pressure of Blast per Square Inch.	Temperature of Blast.	COST OF MATERIAL.							
		Coke.		ATERIAL.	COST.		COST AT GLEIWITZ HUTTE.		
Pfd.	Degrees C.	Sqr.	Pfun		Sqr.	Pfn.	Sqr.	Pfn.	
3	280—300	15	11·9	Fires	—	—	10	6	per Tonne.
3	280—300	14	5·1	....	—	—	19	2	,,
3	280—300	12	8·6	king Coal	—	—	15	3	,,
3	300	12	8·6	....	—	—	3	2	per Ctr.
3	300	10	4·9	....	—	—	4	2	,,
3	300	10	4·9	2 pfund for breaking.	—	—	1	10	,,
3	300	5	4·0	r 100 pfund	—	—	4	7	,,
3	300	5	4·0						
3	300	—	—						

asure equal to 7 1-9th cubi

TABLE OF EXPERIMENTS WITH RAW COAL AT THE BLAST FURNACES AT GLEIWITZ.

No. of Experiment.	Average Number of Rounds in 24 Hours.	Average Proportion of Material per 2 Tons of Fuel. — Ore. — Brown Hematite	Ore. — Mill Cinder.	Ore. — Total.	Flux. — Limestone.	Flux. — Burned Limestone.	Percentage of Burden.	Produce per Round.	Proportion of Coke and Coal. — Coke	Proportion of Coke and Coal. — Raw Coal	Production in 24 Hours.	Quantity of Material Consumed per 100 lbs. of Metal. — Fuel. — Coke.	Fuel. — Raw Coal.	Ore. — Brown Hematite.	Ore. — Mill Cinder.	Flux. — Limestone	Flux. — Burned Limestone.	Small Coal used for Boilers in 24 Hours.	Number of Tuyeres.	Diameter of Nozzle of Tuyeres.	Pressure of Blast per Square Inch.	Temperature of Blast.
		Lbs.	Lbs.	Lbs.	Lbs.	Lbs.	Per Cent.	Lbs.	Per Cent.	Per Cent	Lbs	Tonnen	Tonnen	Lbs.	Lbs.			Ton	No.	Inch.	Pfd.	Degrees C
Ordinary burden when using Coke alone ...	240	550	65	615	252	—	31·00	190·65	100·00	—	45,756	1·019	—	288·44	34·09	132·12	—	15	8	2¾	3	280—300
1	240	565	65	630	241	—	30·76	193·75	91·67	8·33	46,500	0·946	0·085	291·61	33·54	124·38	—	13	8	2¾	3	280—300
2........................	252	590	65	655	250	—	30·50	199·77	83·33	16 67	50,342	0·834	0·166	295·34	32·53	125·14	—	3	8	2¾	3	280—300
3........................	252	590	65	655	—	145	30·50	199 77	83·33	16·67	50,342	0·834	0·166	295·34	23·53	—	72·58	—	8	2¾	3	300
4........................	234	570	65	635	225	—	30·74	195·19	66·67	33·33	45,674	0·683	0·341	292·02	33·30	115·27	—	—	8	2¾	3	300
5........................	236	570	65	635	—	140	30·40	195 19	66·67	33·33	46,064	0·683	0 341	292·02	33·30	—	71·72	—	8	2¾	3	300
6........................	190	550	65	615	220	—	31·00	190·65	33·33	66·67	36,223	0·350	0·699	288·44	34·09	123·26	—	—	8	2¾	3	300
7........................	194	550	65	615	—	135	31·00	190·65	33·33	66·67	36 986	0·350	0·699	288·44	34·09	—	70·81	—	8	2¾	3	300
8........................	172	550	65	615	—	135	31·00	190·65	—	100·00	32,791	—	1·049	288·44	34 09	—	70·81	—	8	2¾	3	300

No. of Experiment.	Cost per 100 lbs. of Metal. — Coke.		Raw Coal.		Brown Hematite.		Mill Cinder.		Limestone		Burned Limestone		Heating Boilers.		General Cost.		Total.		
	Sqr.	Pfund.	Sqr	Pfund.	Sqr.	Pfund.	Sqr.	Pfund	Sqr.	Pfund.	Sqr.	Pfund	Sqr.	Pfund.	Sqr.	Pfund	Rhil.	Sqr.	Pfund.
Ordinary burden when using Coke alone ...	15	11·96	—	—	9	1·60	1	5·04	2	5·06	—	—	—	4·13	5	10	1	5	1·79
1	14	5·11	1	7·55	9	2 87	1	4·77	2	9·36	—	—	—	3·52	5	10	1	5	1·18
2........................	12	8 62	3	2·18	9	4 22	1	4·26	2	3·53	—	—	—	0·75	5	10	1	4	9·56
3........................	12	8·62	3	2·18	9	4·22	1	4·26	—	—	3	3·91	—	—	5	10	1	5	9·19
4........................	10	4·98	6	6·43	9	2·96	1	4·65	2	1·35	—	—	—	—	5	10	1	5	6·37
5........................	10	4·98	6	6·43	9	2·96	1	4·65	—	—	3	3·44	—	—	5	10	1	6	8·46
6........................	5	4·05	13	4·77	9	1·60	1	5·04	2	3·11	—	—	—	—	5	10	1	7	4·57
7........................	5	4·05	13	4·77	9	1·60	1	5·04	—	—	3	2·94	—	—	5	10	1	8	4·40
8........................	—	—	20	1·27	9	1·60	1	5·14	—	—	3	2·94	—	—	5	10	1	9	8·85

Cost of Material — Name of Material.	Cost.		Cost at Gleiwitz Hutte.		
	Sqr.	Pfn	Sqr.	Pfn.	
1. Small Coal for Boiler Fires	—	—	10	6	per Tonne.
2. Large Coal	—	—	19	2	„
3. Coke from Zalirzer Caking Coal	—	—	15	3	„
4. Brown Hematite	—	—	3	2	per Ctr.
5. Mill Cinder	—	—	4	2	„
6. Limestone, including 2 pfund for breaking.	—	—	1	10	„
7. Burned Limestone, per 100 pfund	—	—	4	7	„

The ton referred to in the above Table of Experiments is a measure equal to 7 1-9th cubic foot Rhinish, or about 240lbs. Coke (Prussian zoll. gewicht).

APPENDIX TO MR. D. ROWAN'S PAPER.

The following is an appendix to the paper read by Mr. David Rowan, at Glasgow, on the History of Iron Shipbuilding on the Clyde:—

EXTRACT FROM MR. GILCHRIST'S PAPER ON EARLY IRON SHIPBUILDING.

"Sir John Robinson, of Edinburgh, designed an iron vessel for the passenger traffic of the Forth and Clyde Canal, the date of which is 27th December, 1816. It appears, however, from a minute in the corner of the original design, in the handwriting of Mr. Walter Logan, the superintendent of the canal company's affairs at that date, as also the contractor, Mr. Thomas Wilson, and the two sub-contractors, Messrs. John and Thomas Smellie, who were working blacksmiths, that the vessel was not laid down till the 27th October, 1818, and launched 14th May, 1819. And from the following letter which I have received from Mr. Adam Stewart, the son of the person who took charge of her when plying with passengers, it appears she was not finished until the autumn:—

Maryhill, March 4th, 1864.

SIR,—I am in receipt of your note, and, in reply, beg to state that the 'Vulcan' passage boat started with passengers from Port Dundas to Lock No. 16 on the 15th September, 1819. Regarding the 'Cyclops,' I cannot give any information.—I am, yours respectfully,

ADAM STEWART.

"The 'Vulcan,' above referred to, was built at Faskine, on the banks of the Monkland Canal, near Glasgow, and now after the lapse of 53 years, is still doing duty, not only on that canal, but occasionally on the Clyde. By referring to the drawings, we find the vessel to have been 61 feet in length, 11 feet beam, and 4 feet 6 inches moulded depth. The frames are placed 24 inches apart. The plates are put on vertically, and are 24 inches broad—butting on each frame, thereby entailing a double row of rivets in each frame. The frames are of flat bar iron, formed by hand to the proper angle. Rolled angle iron not having been introduced at that date. A doubling strake forms the gunwale, called by the

designer the gunwale plate, and is made of half-inch plate, 13 inches broad, formed into an angle iron 9 inches by 4 inches, which not only strengthens the hull longitudinally, but the projecting flange of 4 inches forms a support to the wooden fender which runs fore and aft the whole length of the hull. A saloon with glazed sides, extended along about seven-eighths of the length of the hull, the roof of which became a promenade deck for passengers. The builder of the 'Vulcan,' Mr. Thomas Wilson on learning of the experiments of Mr. Robert Wilson, then of Dunbar, now of Patricroft, with the screw propeller, advised the Governor and Council of the Forth and Clyde Canal to alter the 'Vulcan' passenger boat into a steam vessel, and to be propelled by a screw at the stern. As per the following letter :—

ARCH'D. GILCHRIST, Esq.,
Zeland Place.

Grangemouth, 1st Oct., 1864.

DEAR SIR,—I was duly favoured with yours and the enclosed this morning, and sorry I am to state that there are now no copies of communications with my friend Mr. Robert Wilson in my possession. You are aware that I contracted with, in 1818, and built for, the Forth and Clyde Canal Company, the "Vulcan" iron passage-boat, considered the first iron vessel on record. There was no angle iron in those days, nor any machinery, except an old-fashioned piercing machine, purchased from Mr. Robt. Baird, Old Basin. A cast iron grooved block to form the ribs, a smith's fire—one foot kneed at a time considered good work. I recollect visiting my native place, Dunbar, in the summer of 1827, and was so delighted with Mr. Wilson's model steamer, propelled by the stern and side wheels, that I prevailed on him, and he granted me the loan of it, on the condition that if the Canal Company approved of it, I would suggest and advise them to employ Mr. Wilson to produce plans to convert the "Vulcan" into a stern propeller steamboat. Being aware that the chief objection to the first side-wheeled steamboat, built by Mr. Symington in 1801, was the impression that the side paddles caused too much surge and injured the banks, on taking the model home and having made the trial, I found the greatest speed was produced by the side paddles when there was no surge, but when the water was not smooth, the stern propeller produced

fully a little more speed, and caused very little swell. Being convinced that boats of this description were the most likely for coal traders, I took the model to Port Dundas, where it was exhibited in presence of the late Kirkman Finlay, Esq., Governor, and a few other Directors, who appeared satisfied it was a great improvement. One of them, however, seemed to hold by the old system—that no machinery could be made to supersede horse-power for trucking vessels on the canal with greater safety and less expense.

My suggestion was, therefore, deferred to another period, and I am sorry to say there is not one of those gentlemen now in life to witness the number of steam lighters trading on the canal on the principle then proposed.

I have given you a hurried statement, and if it prove worth your notice, and add anything to convince the English folks that bodies on this side the Tweed are rather a step in advance, I will be gratified.—I am, Dear Sir, yours most respectfully,

THOMAS WILSON.

"I am pleased to be able to state that Mr. Thomas Wilson, the builder of our first iron vessel, author of the above letter, is still alive, happy in the great results which were originated by him, in the building of the iron passenger boat, the 'Vulcan,' in 1818; he lives at Grangemouth."

The following is an extract from the *Greenock Advertiser*, of November 3rd, 1840, on the subject of the screw propeller:—

"On Tuesday last, another trial was to have come off on the Forth and Clyde Canal, at Lock No. 16, on a new propeller, the invention of Captain Kincaid, of this town; but, owing to some defect in the boiler, some of the tubes having burst, the steam could not be got up, and on the following day the leaks were stopped by filling up the defective tubes—but this being at the best but a *make shift*, the engine could not be brought to work above 25 to 30 strokes per minute, while, on the former trials, the working power was generally brought up to 60. At this slow rate, however, a speed of about four miles per hour was obtained, which was far above the most sanguine expectation of those interested, and most fully proves the effective force of under-water propelling when properly applied. The new propeller is only two feet two inches in diameter, with four blades or vanes, each showing a

surface of about eight inches square, and the boat in which the trials are made is fifty-seven feet long, eight feet broad, and draws about fifteen inches water; yet this *tiny little thing* to put in motion and propel such a body, at the above rate, and with only the half-working power of the engine, must have been astonishing to all, and may leave those in doubt who have not seen it; but facts are positive things—there was no mistake; and there is no doubt that, at the full-working power of the engine, a speed of seven to eight miles per hour will be obtained. We have not heard what is to be the result of this trial, or whether it is to be further persevered in; but there can be no doubt if the size of the propeller, as recommended by Capt. Kincaid to the Canal Company, of four feet six inches in diameter, were adopted, that a speed of twelve miles per hour would be obtained for the swift boats, or as a tug vessel, to tow them at the rate of ten miles.

"Captain Kincaid is still with us, and on bringing to his mind the above experiment, he informs us that long prior to the above date, the possibility and success of submarine propulsion took firm hold of his fancy, and seeing the superiority it would have over the paddle for war purposes, he, in 1828, proved the principle, by affixing a four-bladed propeller to the stern of the quarter boat of the brig Catherine of Greenock; and on the passage from Bombay, in a calm off the Cape de Verd Islands, he and his passengers, amongst whom were both naval and military, were quite delighted with the success of the experiment."

"The propeller used on that occasion was 18 inches in diameter, was of wood, and as near as possible the four-bladed propeller of the present day. The original is still in his possession, and can be seen any day by the curious at his house of Corrie Bank, Greenock."

REPORT OF THE BELGIAN COMMISSION ON THE WORKING OF DANKS'S ROTARY PUDDLING FURNACE.

[SOME time ago, the iron manufacturers of Belgium, having at several meetings discussed the merits of Danks's Rotary Puddling Furnace, decided to send a commission to England, for the purpose of seeing the working of the apparatus at Middlesbrough, and of testing the applicability of the machine to the qualities of pig iron principally used in Belgium. Messrs. Taskin and Tahon, together with a practical puddler, visited this country in July last, and remained in England several weeks. The report which these gentlemen presented to the Belgian iron manufacturers has been recently published, and we now give a translation of the greater portion of the document in question, omitting only the parts descriptive of the apparatus and its accessories. The Commission state that they were most courteously received by the English trade, and that they were afforded, at the Tees-Side works, every facility for fully investigating the working of the rotary furnace.]

THE PUDDLING.

The Fusion.—With Danks's apparatus, the melting can either be done in the apparatus itself, or the metal may be introduced in a molten state. In our experiments at Middlesbrough, the metal was charged in pigs as in the ordinary furnaces. The operation in that case shows nothing particular; so long as the pieces are not melted, the apparatus remains stationary. Now and then only it is partly revolved, either to displace the centre of fusion, or to

loosen the pigs, or lastly, to expose successively all the parts to the action of the flames. The only care to be taken is to act prudently, because the pigs in rolling too roughly in the furnace might damage the fettling. The second mode, viz., charging with molten metal prevents that inconvenience.

For several reasons, to be mentioned further on, it is advisable that the latter mode should be followed. In this case the operation is of the simplest kind; it is sufficient to carry the molten charge by means of a ladle, or run it through a channel into the furnace, as in the Bessemer apparatus.

Refining.—As soon as the pig iron is melted the mixing is proceeded with as in ordinary puddling. This is entirely performed by revolving the furnace itself. To effect this, the furnace is set in motion rather slowly at first, increasing gradually its velocity so as to reach five or six revolutions a minute; at the same time blast is given so as to produce an active heat. After some minutes silicatisation sets in, the slag becomes liquid and floats on the surface. To complete still more strongly and completely the refining process, a jet of water is thrown violently into the bath. The slag coming in contact with the water tends to stiffen on the surface through the motion of the furnace, the consolidated particles are carried to the bottom, are there reheated and become liquid again. Thence they rise to the surface again, thus washing out the impurities of the pig iron. The latter is, on the other hand, gradually thickening and falling to the bottom continually. The injection of water is eventually stopped, the heating is continued to render the slag as liquid as possible; then it is stopped in order to proceed to the tapping of the slag.

Tapping of the Slag.—To effect this, the tap-hole of the chamber is brought a little above the surface of the bath; it is pierced with a fluted iron bar, and the revolution of the vessel is slowly continued, taking care to stop before the tap-hole comes on a level with the metal. The slag, which floats, is thus easily let off and falls in a proper receptacle. The furnace is then lifted by a reverse motion of the machine, and after the hole has been stopped with clay, the quick motion is resumed.

Decarburation.—At the same time the heat is increased by giving as much blast as possible. The decarburation diminishes, and the metal begins to boil. Revolving is continued and heating

as well, actively; the boiling continues, and the bath rises more and more, so as to reach often the stopper hole.

Lastly, the decarburation ceases, the escape of gases vanishes, the bath lowers. At this point the iron has already completely come to maturity, and shows itself as a granulated body floating in the midst of the remaining slag.

Balling.—The balling of this mass of iron is easily done. To effect this, it is sufficient to continue slowly to revolve the furnace, and soon after the grains unite and form barley corns; these in their turn are welded together, form a ball, and lastly a single bloom of 40 to 50 centimeters in diameter to $\frac{1}{2}$ meter or 1 meter in length. The ball being thus made, the furnace is stopped to examine if some pieces have not stuck here or there in some corner of the chamber or in the stopper-hole. In this case it is pushed back behind the ball by means of a small poker, which is passed through the stopper-hole. At the same time, the end of the ball is pushed and pared with the same poker, or with a puddler's scraper. After this, it is put in motion again slowly. The ball rolling upon itself again is more and more composed, and gathers the last bits which have been brought together in the manner described. After about a $\frac{1}{4}$ or $\frac{1}{2}$ a revolution, the ball is sufficiently compact and regular to be withdrawn and sent to the squeezer. As soon as this is completed, preparations are made to proceed to another heat. This is done by throwing simply in the furnace some hammer or rolling-mill slag, to serve as a bottom for the melting of the pig iron. Thereon are placed the pieces of pigs, the stopper is put in its place again, and successively the series of processes just described are gone through again. If the fettling should require repairs, it is of course necessary that these should be made before the new charge is put in.

We shall terminate the descriptive part of the labour in summing up the observations and principal experiments which we have been able to make on the furnace at Middlesbrough. On our arrival the furnace was blown in and ready for work; it was immediately set in motion, and continued to work for three successive days under our constant survey. After that (through circumstances independent of the state of the apparatus), the work was laid off for some time, and was then resumed for another three days. Every

day, from 4 to 5 heats were made between 6 to 7 o'clock A.M. and 4 to 5 o'clock P.M. In the first instance, grey pig iron was used, then white iron; and subsequently mixtures of both as they are used for the ordinary rolling mills in the neighbourhood. All the pig iron was of local make, and taken from the yard at the works. The white pig iron was of the kind used there for rail-making; the grey iron, alone or mixed, is usually worked up in the manufacture of iron for shipbuilding purposes. The other materials used have been, viz.:—For the fettling, hammer or rolling-mill slag, either alone or sometimes mixed with Blue-billy. For the repairs of the fettling:—The bath was made with Blue-billy; the lumps of Bilbao ore very hard and free from injurious matters. During about thirty heats, we have witnessed only two partial repairs of the fettling, of one section each. The coal used was unscreened coking coal, very nutty and clean, to such an extent that several heats could be made without cleaning the fire bars.

We have noticed that in active working order the maximum of consumption was, 212 kilogr. of coals per hour. The men employed at the furnace were:—

1. A mechanic for the working of and keeping in order the rotatory machinery of the furnace.
2. A stoker attending to the firing, coals and ashes.
3. Two men at the cranes for charging and discharging.

The work was done under the management of the mill manager or of a foreman.

The iron obtained has been examined and tried in every way at the different stages of progress ; we have had it worked in every possible manner into rails, angles, flats, squares, plates, etc.

We have also made the puddler who accompanied us, work the above-named pigs in the ordinary puddling furnaces of Tees-side Works and at those of Messrs. Jones Brothers & Co., of the same town, to compare the makes and control our own observations. Lastly, we have taken care to gather together and bring with us numerous samples of the raw materials used : Pig iron and iron ore and the produce obtained : Slag, rough finished iron, finished iron rolled into rails, angles, plates, etc. We submit them to the judgment of your Committee, together with summary tables of our different experiments:—

TABLE No. 1

Statement of materials used and make obtained during our experiments at Middlesbrough.

DATES,	FETTLING.			Squeezer or Mill Slag.	Coal.	Pig Iron.	Squeezed Blooms.	Tap Slag.	REMARKS.
	FLUX.		LUMPS.						
	Blue-Billy.	Hammer Slag	Bilbao.						
Tuesday, 23 July				573	907	1088	1127	317	4 heats
Wednesday, 24 ,,				660	1100	1360	1429	420	5 ,,
Thursday, 25 ,,	430	40	350	645	1350	1360	1401	405	5 ,, 1 repair
Wednesday, 31 ,,				590	1108	1360	1413	395	5 ,,
Thursday, 1 Aug.				718	1327	1632	1710	517	6 ,,
Friday, 2 ,,	45	444	435	620	1290	1360	1394	375	5 ,, 1 repair
Total......	95	959	785	3798	7082	8160	8479	2429	
To the per cent. rough finsh'd iron	1	10	9	44	83	96	100	28	

The charges operated upon on the 23rd and 24th July were grey Cleveland iron; those of the 25th white pig iron for rail-making; and, lastly, those of the last three days were half white and half grey pigs.

TABLE No. 2.

TIME SPENT IN PUDDLING.

A. DANKS'S FURNACE.

Experiments.	Smelting.	Reducing and Squeezing.	Usual Repairs and Charging.	TOTAL.	Charges, Kilogrammes.*	Kind of Pigs.
	H. M.	H. M.	H. M.	H. M.		
BELGIAN COMMISSION AT MIDDLESBROUGH.	45	38	3	1·23	272	Grey.
	37	30	5	1·12	,,	White.
	43	37	3	1·23	,,	Id.
	48	40	5	1·33	,,	Id.
	50	35	5	1·30	,,	Half white, half grey.
	1·05½	27	5	1·37	,,	Id.
	48	27	,,	1·15	,,	Id.
	45	35	10	1·30	,,	Id.
	45	35	,,	1·20	,,	Id.
Average	47½	34	5½	1·21	272	Cleveland.
ENGLISH COMMISSION IN THE U.S. OF AMERICA.	44	25	,,	1·19	272	Id.
	51	26	,,	1·20	,,	Coneygree.
	40	22	,,	1·14	,,	Derbyshire.
	37	27	,,	1·04	,,	Crystalline.
	46	21	,,	1·07	,,	For Bar-making.
	42	27	,,	1·04	,,	,, Tinplate-making.
Average	43	25	5½	1·08	272	

* 1,015 kilogrammes = 2,240 English pounds.

TABLE No. 3.

TIME SPENT IN PUDDLING.

B. ORDINARY FURNACE.

Experiments.	Smelting.	Reducing and Squeezing.	Usual Repairs and Charging.	TOTAL.	Charges, Kilogrammes.*	Kind of Pigs.
	H. M.	H. M.	H. M.	H. M.		
In England ... Single furnace	35	49		1·24	200	English.
In Belgium ...	45	47	5	1·32	225	White of Ougrée.
,, single f.	35	47	8	1·30	,,	do.
,, dble. f.	30	52	18	1·40	,,	do.
,, single f.	35	57	7	1·39	240	do.
,, ,,	25	55	8	1·28	,,	Cockerill No. 1 and 2.
,, ,,	25	55	10	1·30	,,	Cockerill No. 3.
,, ,,	22	47	5	1·14	,,	Cockerill for rails.
,, ,,	22½	52	17	1·37	220	Couillet ,,
,, ,,	46	57	10	1·53	240	Cockerill No. 4.
,, ,,	54	1·33	10	2·17	225	175 Special Pigs 50 of Ougrée.
Average	34	56	9½	1·38½		

* 1,015 kilogrammes = 2,240 English pounds.

PRACTICAL EXAMINATION OF THE PROCESS.

Having described the apparatus and the *modus operandi,* we will lay down our observations on the principal points, to be taken as the basis for the appreciation of the system. For greater clearness and facility we shall proceed methodically in taking up each part in particular in order to analyse and compare it with the ordinary system.

The Furnace and Accessories.—Considered as a whole, as well as in the details of its construction, the furnace appears to us to have been well studied and combined; all the pieces composing it are strong and the best arrangements are taken to guard those which are more particularly exposed to the action of the heat. The combustion chamber offers nothing particular; it resembles in every particular that of the ordinary furnaces with blast. The only new feature introduced consists in the arrangement of a double row of tuyeres, which come out above the fuel and allow the gases to burn simultaneously, to give more heat and to produce, if necessary, an oxidising flame to quicken the chemical reactions of the puddling. For those reasons this arrangement appears to us commendable even for the ordinary furnaces. The bridge forming one body with the standing part of the furnace, offers nothing very particular. It is traversed by flues of water, which constantly cool it down to the time when the stopper is withdrawn; it is very easy of access, so that it may be repaired, if need be, whilst at work. The movable chamber, which it might be thought would soon get deformed in consequence of the heating, has remained intact since the starting of the furnace. The discs were corroded towards the interior, and even cracked in several places; this, however, did not seem to present any inconvenience, for no one thought of replacing them, although this could easily be done during the stoppage. Moreover, in the new furnaces which we have seen in course of construction, care has been taken to make these discs of forged iron to insure a more complete resistance. The joints between the discs and furnace were also creating some uneasiness; it was feared that, owing to the expansion, the pieces might warp, and that thus the joint might not remain perfect enough to prevent the flame or even the metal or molten slag from oozing out from between the

connecting parts. We have, however, observed nothing of the kind. Sometimes during the boiling, the slag would enter somewhat in the joint, but it soon hardened, and getting crushed between the discs all oozing soon stopped.

The movable end piece seems also to be well combined. Suspended as it is to a railway in mid-air, it is handled and repaired, when required, with as much ease as an ordinary furnace door. The means of closing are also very hardy and strong. They consist of two inclined stays, one leaning in the direction of the fixed incline, the other in that of the axis of the furnace. The stays are fixed and tightened by means of a sliding motion. The distance between the opening of escape of the furnace and the entrance of the chimney is two metres (6 ft. $6\frac{3}{4}$ in.) In cases where it should be found advisable to use the waste gases, this distance might be shortened without inconvenience by shortening the elbow of the movable end piece instead of being placed at the side. The boiler might be placed even in the axis of the furnace, either vertically or horizontally, so as to receive the heat more directly. One engine for each furnace is indispensable; the variations of velocity, of motion, and purchase are too great for one engine to do service for several furnaces. Besides, these engines are, on the whole, not very dear, take up little room, and do not impede the working about the furnace. Lastly, although the apparatus had worked during five or six months, we have not noticed any trace of deformation or of serious dislocation. It may, therefore, be concluded that it will stand a good industrial use.

Fettling.—As regards the fettling inside, it would be necessary to see the apparatus at work for a longer time than we could afford to spend. Considering, however, the repairs which we have witnessed, there does not seem to be any fear of any serious inconvenience occurring in this respect. One thing only might make the mind uneasy: that is to know if by ordinary means the necessary material could be produced suitable for the fettling. Now, this question seems to be solved in a satisfactory manner: a list has been given already of numerous ores which can be used for fettling or for lumps, and further experience will no doubt bring others to light. But supposing even that recourse has to be had to foreign parts or to artificial manufacture, at a high price, there will always be a compensation from the fact that by their reduction

these ores yield a large percentage of iron to the charge. It has been shown that the ore used for the purpose yields 50 per cent. to 60 per cent. of the metal it contains. Taking that on an average 30 per cent. of this ore be used for every 100 kilogrammes of puddled iron obtained, and that the yield of iron in the ore be 60 per cent. iron, it would add from 9 to 10 kilogrammes per cent. of the iron produced This shows that there is a margin, and that far from being a drawback, the use of a rich ore becomes here rather a source of profit.

We have analysed the apparatus as well as the manner in which it appears to us that it can stand the usual work; we shall now examine how it performs the mechanical and chemical operations which constitute puddling properly speaking.

The Melting.—As stated before, this can be done either in the apparatus itself, or by introducing the metal in a molten state into it.

The first mode is not advisable. In the first instance, it is somewhat dangerous to the internal fettling. In fact, in order to render the smelting more active, and to prevent the lumps and slag from corroding the fettling too much by melting in the same spot, the charge has to be now and then displaced by a partial motion of the furnace. But it is easy to understand all the danger of this manœuvre. The solid lumps, in sliding, plough the fettling and act upon it as scrapers. Sometimes also they stick to the sides, and when getting loosened always carry with them some part of it. It follows that in either case, whether the apparatus be at rest or in motion, there exists an inconvenient alternative for the fettling. Secondly, the melting in Danks's apparatus requires a considerably longer time than in the ordinary furnace. From Table 2, it is obvious that to melt a charge in the ordinary furnace, takes on an average 25 to 30 min., whilst in Danks's 40 to 45 min. are taken up, or about one-half longer, and this cannot well be otherwise. The circular form used for the puddling chamber is not the best for an active and advantageous heating. The bridge will always be higher and the vault more arched than in the ordinary furnace, where one is not bound thus by an absolute form. In performing the melting in a special furnaee, all the inconveniences just pointed out are done away with. Moreover, all the time for melting is saved, which is 40 to 45 minutes ou 1 hour 20 minutes, which time

a whole puddling operation requires in Danks's furnace. Therefore, the number of heats can be more than doubled. There will also be a considerable saving of fuel. In a cupola the consumption of coke is generally taken to be 15 kilog. of coke for 100 kilog. of pig iron, whilst the ordinary puddling furnace requires at least 25 kilog. of coals to smelt 100 kilog. of pig iron. And lastly, the smelting in a special furnace may be considered as a starting operation, which will still facilitate and improve the work of puddling. These advantages are so well understood that in all the projected erections of furnaces, steps are taken to do the smelting in the cupola.

Refining.—The means of refining have undergone more particularly improvements in Danks's furnace. The hand puddling is entirely suppressed; instead of having to stir with his rabble the bath during the whole period of refining, the workman has nothing more to do than direct the motion of the machine and survey the phases of the operation. Having thus done with the most painful part of the labour, he can give more attention to the remainder, and therefore obtain better results. The mechanical means used to produce the puddling motion seems to us very practical, and obtains the end more completely than the rabble of the workman can do it. Thanks to the lumps of ore which project in the interior fettling, at the least motion of the apparatus, the bath is being violently shaken, and a most energetic and complete puddling is produced in the entire mass. We, moreover, point out as an improvement from a "better refining" point of view, the use of the jet of water thrown on to the boiling bath. We need not insist on the effect produced by this reaction; it has often been recommended to throw out the sulphur, but until now practical inconveniences had prevented its application in the ordinary furnaces. Lastly, in the ordinary puddling system, the oxygen required for the chemical reactions is only supplied by the flame of the hearth, and the atmospheric air which enters the furnace. The action of these gases can have effect only on the surface of the bath. In the new furnace, this oxygen is supplied besides by the decomposing of the oxide of iron of the fettling. The latter has therefore a double advantage over the former. Firstly, it presents itself at the moment when its affinity for other bodies is greatest; secondly, being produced at the bottom of the bath, it is compelled to traverse the whole boiling mass, and its action is therefore more complete

and general than when it only touches the surface. The results obtained, moreover, clearly prove the superiority of the means used. Thus the quality is greatly improved, the iron is better refined, and its nature more homogeneous. The fracture, in fact, is always of a uniform aspect, and unlike what is shown in rough finished hand puddled iron, one does not see grained and fibrous parts. Moreover, the time used in the refining is much shortened; against 50 or 60 minutes usually required for refining in an ordinary furnace, 25 to 30 minutes—therefore the half—is required in Danks's furnace, and moreover the charge in the latter is, as is well known, much greater. Lastly, we call attention to the fact that neither the quality nor quantity of the pig iron used have any influence over the time required for the refining. No matter whether the pig iron be strong or soft, whether 200, 300, or 400 kilog. are operated upon, there is nothing to show that the work has proved more difficult or requires more time. This is shown to such an extent, that although it has been said that grey pigs were easier and readier to treat than white ones, we have not detected any difference on that head. We are even of opinion that the reaction is so active and general that a little more or less carbon to be taken away has no great influence over the progress of the operation.

Balling.—The balling in Danks's furnace is done well and quickly; as soon as the iron comes to maturity, a few revolutions of the apparatus bring the mass together, and the ball is made by itself by means of the rotation. The workman only interferes accessorily towards the end, to arrange the end of the ball and bring together the pieces which may have remained uncollected. The ball thus obtained is generally pretty regular and more compact than that from ordinary furnaces, and this is accounted for by the greater weight of the mass and the greater energy or force with which it is rolled about in the apparatus.

Squeezing.—Although a special apparatus for the squeezing of such a mass be preferable, and even indispensable for a well organised works, the steam hammer may be used satisfactorily, provided that its weight and fall be sufficient. The one we used in our experiments weighed 4½ tons, and its fall was 1½ metre, and with this a ball of 300 to 400 kilogrammes could be squeezed pretty well. The only drawback was (and this will always take

place with the steam hammer) that it was worked too slowly, and the bloom had to be re-heated before it could be sent to the rolls. With a special squeezer probably re-heating may be avoided and the bloom passed at once through the rolls.

Weight of the Bloom.—If the means used for blooms of 40 to 50 kilogrammes are taken into account, it must be clear that those of 500 kilogrammes and more, as now being obtained, may prove somewhat inconvenient for a good finish. However, considering the benefit which may be gained thereby, it will be found that very often the producing of such large blooms will rather be an advantage. This will always be the fact in all cases—and we know that they are numerous in the trade—where an absence of the joints welding and the homogeneousness of pieces are indispensable. Certainly in rolling iron into bars, and submitting it to successive draws, it gets refined and fibrous, perhaps even strengthened, but this is often at the expense of good welding and the homogeneousness of the piece to be produced further on from thousands of pieces piled up together, Would not the same result be obtained simpler by suppressing some draws and by acting upon one mass of better materials? It is there, we think, that the real progress may lie hidden, and we believe that in future, instead of trying to unite a number of pieces in order to make one whole, it will be found more logical to begin by making one whole, which may then be divided in pieces of a certain weight. Moreover, it would not be impossible to divide the bloom either before or after, or even during the squeezing. For those who find it necessary, a pair of shears, or a system of saws, could easily be appointed for that purpose.

But, at any rate, this division will produce much more trouble and expense than if a bloom of one piece were acted upon. Supposing, for instance, that it be desirable to divide it into three pieces, the pieces ought to be squeezed and hammered at the same time, or else the second, and principally the last, would cool down too much. This would require three sets of hammers and squeezers, which requires a larger plant and greater number of workmen, and therefore greater expence than when the whole is worked up at once. Besides, it is easy to be foreseen that the reheating of the squeezed blooms will become indispensable before rolling them into bars.

ECONOMICAL CONSIDERATIONS.

Production.—From the notes taken in America by the English Commission, we gather that 100 kilogs. pig iron have produced 116 kilogs. puddled iron. From our own observations we find that 100 kilogs. pig iron have produced only 104 kilogs. puddled iron. We shall first explain that this difference arises from the fact that in America usually 10 per cent. of the charge was made up of iron waste, whilst at Middlesbrough only squeezer slag was used. Moreover, in the former instance, the weight was taken of blooms squeezed by Danks's squeezer; in the latter, it was taken of hammered blooms, and which contained less cinder. However, this may be, the increase is important enough, because by the ordinary process generally 85 per cent. only is obtained. Now, be this result due to the direct reduction of the oxide of the fettling by means of the carbon from the pig iron or from the flame, or to any other cause, this we say is a pure scientific question on which we need not dwell. Let it, therefore, be sufficient for the present to state and affirm the fact, because the scales have each time revealed it. In order to take away any doubt on this head, we may add that this result which had at the outset appeared to be paradoxical, is not inherent to Danks's furnace alone, and that it may be obtained, or at any rate, very nearly so, with ordinary furnaces as well. It suffices to obtain it to use the same materials for fettling. Thus, at Messrs. Jones Brothers and Co. we have ascertained by inspecting the books of the make, that similar results are there currently obtained. Moreover, we have been enabled to test these results by working ourselves one of the furnaces of that firm. In those experiments, with a fettling of best cinder, we have obtained 97·4 per cent. of puddled iron and billets, and the Belgian puddler who accompanied us, however inexperienced and awkward he might be, in the presence of an unknown apparatus and strangers, has produced magnificent fine grained rough finished iron with only 5 per cent. of the waste of pig iron. Now, if we bring together these makes (of 97·4 and of 95 per cent.) with the real weight contained in 100 kilogs. of raw pig iron (and which we estimate at 92 per cent.), we show that even with the ordinary furnace we can obtain as in Danks's, more puddled iron than there exists in reality

in the pig iron charged. We may add, however, that with Danks's furnace the make is always stronger than with the ordinary furnace, because there, in all the parts of the chamber which may come in contact with the metal bath, there is a complete absence of bricks and siliceous cement. Here we may be permitted to make a a digression by a few words, and call attention to the obnoxious consequence of the silica or refractory matter of an inferior quality in furnaces to work either iron or pig metal, whatever they may be. It is known that silicon and silica cannot be near molten pig iron or white heated iron and an oxygenated body, without transforming the silicum into silica and the latter into silicate. Now, in puddling furnaces, and even in reheating furnaces, unless there be another base present, the whole oxide required for the transformation of the silicate is supplied by the pig or iron, which thus passes into the slag. If it be reckoned that for one kilog. of silica about four kilogs. of iron are required to form thus a silicate, it is easily to be seen that at any price the presence of sand in the furnaces should be prevented. Therefore, arches, bridges, or screens of any kind ought to be prohibited as well as any brick or cement of an easy smelting tendency, more on account of the waste of iron which it produces, than of the wear and tear or cost of repairs. For the same reason every care should be taken to choose a fettling as much as possible free from silica. Lastly, it should be insisted upon that the pigs be run in cast iron moulds, or at least, that the casting into sand be not susceptible of producing pigs so loaded with useless matter as they generally are. Sure enough, the founder may find it profitable on account of economy and overweight, but be it known to the puddler that it is so much iron less he has got, and then, and this particularly we repeat, that for one kilog. of sand which remains in the furnace, four kilogs. of iron go to waste in the slag.

Make from one Furnace.—In our experiments, the charge of pig iron was 272 kilogs. The average make has been 283 kilogs. We have stated that from 4 to 5 heats were made between 6 and 7 o'clock a.m., and 4 to 5 o'clock p.m., which would allow for 6 to 7 heats in 12 hours, and then the make would be about 1,800 kilogs. At Cincinnati, the English Commission has, under similar circumstances, found an average of from 6 to 7 charges, giving a make of 1,990 kilogs. By both parties the

melting was done in the furnace itself. Now, according to the notes taken by us as to the time required for the different periods of the work, we have found that the melting takes about 45 to 50 minutes, whilst all the remainder (refining and balling, charging and discharging), only requires from 25 to 35 minutes. It may, therefore, be taken unhesitatingly for granted, that if the pig iron were introduced in its molten state, the number of heats found above would be doubled, *i.e.*, from 12 to 14 heats, giving 3,400 to 4,000 kilogs. a shift. But it is ascertained that it does not require much more time—the furnace being constructed for the purpose—to work a charge of 500 than one of 300 kilogs. Thence we conclude that, combining the furnace in a manner to produce an average make of 500 kilogs. per heat, ten heats might be calculated upon with certainty, or say a make of 500 kilogs. per shift and per furnace. This is, as shown clearly, the make of 3 or 4 ordinary furnaces.

CONSUMPTION OF COAL.

Quality.—The coal used, although not picked on purpose, was of very best quality, strong, clean, and nutty. It is not to be concluded therefrom, however, that only first-class fuel can be used. Of course if it can be had, as was the case here, it will always be well to take it; but as we have stated before, the heating chamber of Danks's furnace being the same as that of ordinary forced air furnaces, we must, it appears to us, come to the conclusion that all our ordinary forge coals may equally well be used in it.

Quantity.—For the same reason, the quantity of coal consumed, depending principally on the section of the bridge and the pressure of the blast—and this latter being the same in both—the consumption ought not to be greater in Danks's furnace than in the others. We have ascertained in fact, that the quantity consumed was 212 kilogs. of active firing per hour, or about 5,000 kilogs. in 24 hours continual working, which represents very nearly the normal consumption of an ordinary furnace with forced air, the grate of which would be, as in this case, 1·20 metre × 0·90 metre.

PRODUCTION OF STEAM.

Danks's furnace is not well fitted, at least, as regards the arrangement of the work, to the utilising of the waste gases in the heating of steam boilers. During the work, the flames get out of the furnace and go to the chimney just as much as out of an ordinary furnace, but it will be observed that at each charging or discharging the communication between the furnace and the chimney is completely cut off. The flame from the furnace is at this moment replaced by an atmospheric draft, which cools down considerably the generator. To prevent this inconvenience, which only lasts from 4 to 5 minutes at the utmost, the stopper hole might be closed by some means to keep in the heat whilst the flame of the furnace is cut off. The boilers which we have seen, and intended for those furnaces, were of the vertical system with an inside flue serving as chimney. The cylindrical body was 1·25 metres in diameter, and the flue 0·60 metre. This was traversed by 8 conical tubes (Galloway system), 7 inches or 0·175 metre diameter. The height of these boilers is 9 metres, and the minimum water-level is at $\frac{2}{3}$ of the height. In these conditions the direct heating surface is about 14 square metres. It was calculated that such a boiler would raise sufficient steam to work the engine of the furnace. In the organisation of a complete works, special boilers, therefore, would be required for the raising of steam for the blast engine, squeezer apparatus, rolling mills, &c. We have stated before that the consumption of coal per furnace would be about 5,000 kilogs. in 24 hours, and in another place that the make is estimated at 10,000 kilogs. The consumption of coal would, therefore, be only 50 per cent. of the iron made. In ordinary puddling it is about 100 per cent. There would be thus left 50 per cent. of coals to be disposed of for the supply of this want of steam, and for the melting of the pigs in special furnaces. Taking for the melting in the cupola 10 per cent. of coke, corresponding to 15 per cent. coals, there would then be left 35 per cent. of coals to be disposed of for steam.

For a works established to make 100 tons rough finished iron in 24 hours it would take 35 tons of coals, or 1,457 kilogs. for the fire-places. In using boilers to burn 5 kilogs. of coals per horse-power per hour a compensation might be obtained of steam for 291 horse-power, and this independently of that already raised by the furnaces themselves.

SPACE REQUIRED.

GENERAL ARRANGEMENTS OF A DANKS'S PLANT.

The rotatory furnaces do not require more space than ordinary ones; on the contrary. The total length of a furnace from the outside wall of the hearth to the stopper hole is 4 metres; its largest width, including the engine, is 3 metres, or 12 square metres for the space of one furnace. The greatest height does not exceed $2\frac{1}{4}$ metres. Considered alone, the furnace requires somewhat more space than an ordinary furnace; but, taken over the whole of a works, they require less space, because they may be placed nearer together, on account of the short and easy movements the work requires. The distance of two furnaces of one group from one axis to another is estimated at 5 metres, and at 7 metres the distance between two groups following one another. From the cupola to the first furnace, as from the last furnace to the squeezer, the distance may be fixed at 8 metres. The total length, therefore, from the cupolas to the squeezer may be put down for three successive groups of two furnaces at about 45 metres, or 50 metres including the space behind the squeezer. Placing the furnaces in two rows facing one another, a space of about 10 metres should be left between them for circulation and working about the furnaces. This gives for the width 10 metres of space, plus twice 4 metres for the furnaces, or 18 metres between the two outside facings of two opposite furnaces. Leaving 3 metres more on each exterior side for the service of coals and ashes, we arrive thus at a total width of 24 metres for a double row of furnaces. The total length found above being 50 metres, it requires about 1,200 square metres for the complete establishment of 12 furnaces and squeezer. An establishment of this kind could supply the make of 40 ordinary furnaces. It is shown, therefore, that, on the whole, Danks's furnaces require less space than other furnaces for a given make.

HANDS EMPLOYED.

We have seen that the puddling, being done entirely mechanically, all the work about the furnaces is simply reduced to the charging and discharging of the materials and the management of the fire and the engine. It follows that, the work being simplified, the number of people employed may be proportionally reduced. Placing the furnaces two by two, we estimate that every group

would require:—1st, one foreman to direct the working of two furnaces; 2nd, one machinist for the direction and the keeping in order of the two corresponding engines; 3rd, one stoker for the management of the two furnaces and the delivery of coals and ashes; 4th, three workmen for the sundry movements of the crane, taking the charge to the cupola, and bringing the bloom to the squeezer. In all, six men for the service of two furnaces (or 36 for 12 furnaces), exclusive of those for the squeezing apparatus and the cupolas. Forty ordinary furnaces would require 80 puddlers and underhands, exclusive of the sets of coal leaders, cinder leaders, &c. The service of the squeezing apparatus will also be easier. The average weight of ordinary blooms may be estimated at 40 kilogs. a piece. For a make of 60,000 kilogs. in 12 hours there would be 1,500 pieces of this kind to squeeze, say 125 an hour. To do this it would take at least 4 steam hammers and two trains of rolls. With Danks's furnace, with blooms of 500 kilogs., 120 pieces would only be required in 12 hours, or only 10 per hour. For this one squeezer and one train of rolls will suffice, and perhaps even squeezer and rolls may be attended to by the same sets of men. Undoubtedly, and especially when considered that cranes and the necessary apparatus will be provided, it will be easier and less expensive to work 120 pieces of 500 kilogs. than 1,500 pieces of 40 kilogs.

EXPENSES OF ERECTING.—COST PRICE.

To finish the analysis of the system we would have to establish a statement of the cost price and an estimate of the erecting expenses. In the presence, however, of the material impossibility to collect together exact documents, and of the variations of the elements, we prefer limiting ourselves to placing in comparison the principal articles which differ in the one case or the other, and to leave it to every one to make, as may be required, his own estimates according to time and place.

EXPENSES OF FIRST ESTABLISHMENT.

Ordinary System.

N.B.—£1 sterling = 25 francs 25 cents:—

40 Furnaces at 3,000 francs each... ...	120,000 francs.
4 Steam hammers	50,000 ,,
	170,000 francs.

Danks's System.

12	Furnaces, with Engines, at 12,500 francs	150,000 francs.
2	Supplementary Boilers	25,000 „
3	Cupolas, with Charging Apparatus, Blowing Engine, Pipes, etc., at 10,000 frances	30,000 „
1	Squeezer	25,000 „
		230,000 francs.

therefore, 60,000 francs in favour of the old system, and for the expenses of first establishment. But against this are to be set off in favour of the new system, a great reduction upon the cost of land, buildings, boilers, piping, chimneys, steam-hammers, rolls, tools, &c., which would be evidently less high in consequence of the work being more concentrated and simplified. As regards the elements of the cost price we find :—

HANDS.

Ordinary System.

80	Puddlers at 8 francs	640 francs.
80	Underhands at 5 francs	400 „
160	Special Workmen for	1,040 francs.

Danks's System.

12	Foremen at the Furnaces at	8 francs ...	96 francs.
	(MACHINISTS).		
12	Enginemen at	4 „ ...	48 „
12	Stokers „	4 „ ...	48 „
36	Labourers „	4 „ ...	144 „
72	Men (of which 12 only of the trade)	...	336 francs.

or 84 workmen less, and a decrease in daily wages of 704 francs, or a reduction of 55 per cent. in hands and 68 per cent. in wages.

We may still add that in consequence of the reduction in the number of furnaces, the supplementary hands of hammerers, rollers, leaders of coal and cinders, foremen, &c., will be reduced as well. As regards coals we have shown that 35,000 kilogs. are saved every

day in puddling, and may be used for the heating of the supplementary boilers. We doubt that this quantity is consumed by a long way. On the other hand, we have seen that the quality is improved and that the output is considerably increased. There would, therefore be two items more which will tell favourably on the cost price. To sum up, therefore, the expenses of first establishment would not be much higher. From the fact that the work has become absolutely mechanical, easier, and the number of hands reduced considerably, there is no doubt that the cost price will be lessened in proportion.

[The Commissioners state that 74 Danks furnaces were at that time building in England.]

CONCLUSION.

The work just finished consists of three parts. The first, wholly descriptive, contains the general exposition of Danks's system, *i.e.*, of the apparatus and means first to work by the American inventor for the mechanical puddling of iron by means of his rotary furnace. It is completed by the statistical documents resulting from our observations and experiments in England and Belgium.

The second, and according to our opinion the most important one, examines impartially the apparatus and means principally from the point of view of their application to the metallurgic industry of our country and the materials at its disposal.

The third is devoted to the economical side of the process. In a comparative study of the two systems, the process by hand and the mechanical process, we have tried to establish a basis by which those whom it may interest can calculate the pecuniary advantages of the American system. The elements were wanting to make this calculation in a precise manner, but let it be considered that Belgium possesses 700 to 800 puddling furnaces, the annual make of which is about 700,000 tons of rough finished iron, and it will be admitted that whatever may be the benefit which the new puddling system brings to 100 kilogs. of iron, spread over such a figure, it must be considerable.

From the whole of this work, we arrive at the following conclusions:—

1. Dank's apparatus is a practical success, and susceptible of a regular and prolonged progress.

2. It does away with the puddling by hand, and replaces it by mechanical motion, more advantageous to the refining process. The consequence is the reduction of hands and the cost of labour.

3. The make is greatly increased, and the quality improved at the same time that the yield is better.

Besides these advantages there exists another very important one which must not be lost sight of. In doing away with the manual labour, the new system not only diminishes the number of hands but, at the same time, shields the trade from a situation which renders it too dependent on the weakness and fancies of the working men. It is known that the puddling of iron requires, on the part of workmen, an amount of knowledge which he can only acquire by a slow education and long practice.

These two points constitute the strength of the workman in bad times, and throw him on the road to unions. With mechanical puddling, all workmen becoming able to do the same work, the danger of any unions is put aside. The rotatory furnace answers, therefore, admirably the requirements of an easy, prompt, regular, and economical labour; and we can only endorse, in our turn, the eulogious conclusion at which the British Iron and Steel Institute arrived in favour of its inventor, at the meeting in London, in March last, viz.: that, by this machine, he has well deserved the thanks of the iron industry and of humanity.

From the iron industry, in supplying three of its great requisites: improvement, economy, and independence of labour.

From humanity, by withdrawing a numerous class of labourers from the exactions of a hard labour dangerous to their health. Capital and labour both will be benefitted by it. Since the invention of puddling by Cort, in 1784, this is one of the processes which has most kept alive the attention of inventors. Other innovations may succeed one another, or the rotatory furnace may yet, perhaps, be modified advantageously by study; but, in the present state of things, it constitutes a great step towards the desired end. It will, at any rate, have a favourable influence on puddling in the ordinary furnace, in the manner that it has opened the way towards new studies on the oxides and sundry materials suitable for fettling puddling furnaces, and that it has

brought to light all the advantages which may be derived from it. It is entitled, therefore, to be recorded as one of the best inventions to bring new life to the ancient iron metallurgy.

NOTE.

The price of 12,500 francs which we have given as the value of the furnace in the estimate of erecting expenses is the actual cost of the apparatus with its accessories in England. It will be seen by the following note of weights of the different pieces of which it is composed that this price may be considerably reduced when the system shall have been fairly introduced into the current manufacture of our country:—

Names of the Pieces.	Weight in Kilogram.	Price per 100 kilogs.	Sums.	
		Frcs.	Frcs.	Ct.
Stays, with their Accessories	1365	30	409	50
Rotatory Chamber	4760	40	1704	0
Moveable Piece and Rings	650	40	260	0
Stays of the Hearth, and Accessories	3080	30	924	0
Suspension Crane, for the Moveable Piece ...	112	100	112	0
Complete Engine	1590	100	1590	0
Sundry Pieces...	300	100	300	0
Total	11857		5299	50

It may, therefore, be said unhesitatingly that in Belgium, if it were not for the anomalous circumstances of the present, the cost of the apparatus would be reduced by more than half—the proportion of make not to be overlooked—and would stand out cheaper than that of the ordinary hand-puddling furnaces.

ON THE FOSSIL IRON ORE AND ITS ASSOCIATES IN SOUTHERN PENNSYLVANIA.

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INTRODUCTORY.

In the middle silurian times, upon the North American continent, when the waters of the old salt sea broke upon a gently sloping coast, and the shallow waters abounded in numerous forms of the lower orders of animal life, were laid down those alternating beds of shales and limestones, which are now known, in the nomenclature of the Pennsylvanian Geology, as the "Surgent Shales" (number V.), equivalent to the Clinton group of the New York Geologists, and of the Wenlock of Murchison. The Surgent shales form a group varying in thickness from 500 to 1,600 feet, following after the Levant sandstones (number IV.), equivalent of the Medina beds of New York, and of the Caradoc of Wales; and succeeded by the Scalent group (number VI.), the equivalent of the Lower Helderberg limestone of New York. The relations of their horizon to the other Palæozoic beds in the geological column will be better understood by consulting the accompanying "Columnar Section" exhibiting the formations in the Palæozoic strata of Pennsylvania, with their New York and English equivalents, compiled by Mr. Jno. Fulton, of Saxton Penn.

In the Surgent shales occur, in three distinct horizons, *three zones of iron ores,* viz., (1) the *Levant iron ore,* near the base of the Surgent series; (2) the *Twin beds of the fossiliferous iron ores,* from 700 to 1,000 feet above the Levant ores; and, lastly, (3) the *Hematite iron ores,* which occur in close proximity to the lower limestones of number VI., or the Scalent series. Of these iron ores, by far the most important for its metallurgical value is the Twin

group of the fossil ore, variously known as the "Clinton ore," the "Dyestone ore," the "Juniata ore," and by other local names, but always the same ore, remarkable for its purity, its general uniform structure and distribution, and for the high quality of the product made from it. Extending, as it does, for at least a thousand miles from the state of New York to Alabama, with a thickness rarely less than two feet and sometimes more than twenty feet, it is believed to be, of all deposits of iron ore in the known world, the most extensive and important. This is especially true where it occurs in immediate proximity to good fossil fuel, and along established lines of transportation, and thus in convenient proximity to markets.

GEOLOGY OF THE FOSSIL ORE REGION.

The geology of the Appalachian mountains is peculiar, and has been beautifully unfolded by the labours of the Professors Rogers and their associates. In order to comprehend how beautifully nature has arranged the great elements of material wealth in this region, it is essential to study somewhat into the details of the geology. A glance at the geological map of the State of Pennsylvania, which accompanies the official report of Professor H. D. Rogers, will guide the eye of one unacquainted with the structure of the great system of parallel foldings, by which the stratified deposits of the State have been thrown into a series of canoe-shaped troughs, whose axes are essentially parallel with the backbone of the main ranges. By these foldings the lower members of the stratified beds have been brought to the surface, and their edges exposed by subsequent denudation, forming now the ridges, and again the hollows, of the long trough-shaped valleys, according to their relative position and hardness. The observer may thus, in a few miles travel, cross, in a line, at right angles with the axis of the valleys, the entire series of sediments, from the Primal sandstone (number I.), equivalent to the Potsdam of New York, and the Lingula flags of Wales, to the upper coal measures (number XIII.), corresponding to a vertical column of sediments from 10,000 to 25,000 feet in thickness, according to the locality chosen for the measurement. This column is given in detail in the vertical section already referred to.

GEOLOGICAL SECTIONS.—TOPOGRAPHY.

The Geological section of the Broad Top Coal and Iron Region, which is annexed, may be studied with great advantage in connection with the general map of Pennsylvania. The intimate and essential dependence of the topographical features of the whole region upon the geological structure of the country, is clearly seen by a simple inspection of this section from west to east through the Broad Top region, which also illustrates perfectly the manner in which the coal beds are brought in convenient proximity to the iron, and both to the lines of drainage and inter-communication through the long trough-shaped valleys in which the railways run beside the rivers.

The numbers of the formations seen in the vertical columnar section are repeated on the horizontal one, and furnish the most convenient means of comparison.

Commencing upon the rich agricultural district of Morrison's Cove, on the western slopes, or back of Tussey's Mountain, where the observer stands on the Auroral limestone (number II.), the equivalent of the N. Y. Trenton limestone, we see the upturned edges of all the formations from numbers II. to XIII., with their easterly dips becoming more and more gentle, until we reach Broad Top Mountain, where the coal measures are undulating, and nearly horizontal. Passing on in the same direction, still further east, we leave the coal measures, as we descend into the valley of Trough Creek, which is a valley of erosion, excavated in the carboniferous limestone, or umbral red shales (number XII.), repeating on the eastern margin of the coal the same formations which we have before passed on the west, but of course in a reversed order, and with westerly dips. Sidling Hill, which forms the easterly margin of the Broad Top, is the outcrop of number X. (the sub-carboniferous sandstone), which, on the other edge of the trough, is known as Terrace Mountain.

I select this section, from the auroral limestones at the base of the column upwards, through the coal measures to the carboniferous conglomerate or *barren measures* (as they are called in Pennsylvania), because it shows clearly the relations of the various geological horizons to each other, and to the general topography of the country; and also because it is a *typical section,* which we

find constantly repeating itself, as we travel either north or south, along lines of direction of the great parallel valleys, or canoe-shaped troughs, into which the whole region is folded by the upheaval of the Appalachian mountains. Tussey's Mountain, at the point selected for the section, is repeated in Wills' Mountain and Evitt's Mountain, Buffalo Mountain, &c., while the Woodcock Valley repeats itself in Black Valley, Cumberland Valley, and Milligan's Cove. Denudation has removed the coal measures in many places, but we find the Broad Top coal repeated in the Cumberland measures, over thirty miles south, thus affording an unlimited supply of the best fossil fuel at both ends of these valleys, and within a very moderate distance, by railways of easy gradients and cheap construction, passing through fertile agricultural districts, abounding in timber on the mountains, fit for all mining and railway purposes. When, therefore, we are once familiar with the Tussey's Mountain section, we are masters of the situation wherever we again find the same rocks.

The chief points of interest in this section are:—

1st. *Tussey's Mountain, with its iron ores.*

2nd. *The Broad Top Coal region* with its excellent fossil fuel repeated again in the Cumberland coal region.

3rd. *Warriors Ridge with its Hematites* and *Woodcock Valley,* in which are the Raystown branch of the Juniata River, and the line of the Huntingdon and Broad Top R. Road. In this valley (and its congeners), are the limestones of the scalent and pre-meridian number VI. and VII. so important as the flux for the iron ores of this region.

Tussey's Mountain rises for seventy miles like a gigantic rampart of these old sediments thrown up to the height of one thousand feet. Its crest is as level as the horizon, and its structure as regular as masonry laid in courses. The top of the ridge is formed by the Levant sandstone (number IV., equivalent of the Medina or Caradoc sandstone,) upon which rest, in perfect conformability, the Surgent shales number V., equivalents of the Clinton or Wenlock. In the Surgent shales exist, as has already been stated, the iron ores which have given fame to the Juniata region.

The twin beds of the fossil ore have, in the Bedford region, an average thickness of over three feet, reaching in some places even

five or six feet. It is, especially in the northern portions of Tussey's and Wills' Mountains, sub-divided into two beds, giving it the twin character. In the lower portions of the same ranges, this twin-like character is subordinated by the thinning out of the intermediate shales, often bringing the upper and lower seams together. The upper bed is often designated as "soft fossil ore," when it has by percolation of atmospheric waters become hydrous. Both beds abound generally in various forms of organic life, encrintal stems and fossil shells, but these sometimes give place to an oolitic and lenticular structure, with minute grains resembling flax-seed; where the atmospheric influences have been less prevalent, these beds are more or less calcareous. The softer and more hydrous forms of this ore yield in the furnace an average of 42 per cent. of metallic iron.

The accompanying diagrams show three sections of the twin beds of the fossil ore and its associated rocks as measured, at the localities named, by Mr. Fulton.

The "*Hard Fossil Ore*" or lower stratum, is usually about one foot in thickness, and is often separated from the soft fossil by an intervening bed of sandstone of variable thickness, from a foot or two up to eight feet. It has generally in its structure an abundance of well-marked fossils, all converted to hematite. Sometimes it takes on the form and appearance of red hematite, which ore is not to be confounded, however, with the so-called hematite of the adjoining limestone beds of number VI., which is brown hematite or Limonite. The blood red powder of the hard fossil ore, following the blows of the hammer, immediately betrays its true character. This variety often has over 60 per cent. of metallic iron.

Both of these twin beds of the fossil ore are probably due to the decomposition, by atmospheric influences, of beds of carbonates of lime and iron. The lime has been removed and the iron converted at the same time to the state of peroxide or red oxide. This view was first suggested by Professor Rogers in his report on the geology of Pennsylvania. It follows as a result of this view, that the valuable deposits of the fossil ore should be limited in depth by the horizon of surface drainage. Experience has, however, shown this view to be only partially true, for in some localities these beds have been mined much below water level. It is these twin beds of

fossil ore which have given celebrity to the "Juniata iron" and the Clinton ore beds of New York, from which vast quantities of these ores are annually transported to the furnaces of Northern and Eastern Pennsylvania. Wherever this bed of ore crops out, it is highly esteemed, and eagerly sought after. It is sometimes mined when reduced to no more than 6 inches in thickness, and is often transported to great distances.

BROWN HEMATITES.

The Brown Hematite of this region occurs in the limestones, numbers VI. and VII., in front of the fossil ore. This ore exists in pockets, or bunches, sometimes of large size, scattered through the croppings of the limestone, as is usual with hematites. These ores have been extensively mined for the Hopewell furnaces, where, for many years, they have been used in connection with equal parts of the fossil ore, yielding about 50 per cent. of metallic iron of excellent quality.

LEVANT IRON ORE.

The Levant ore, locally known as the "back vein," exists from 700 to 1,000 feet below the fossil ore, and but a short distance below the white sandstone of the Levant series, number IV., which forms the crest of Tussey's Mountain, Will's Mountain, Dunning's Mountain, &c. This bed of iron ore, which sometimes assumes gigantic proportions, is also at times represented by a bed of ferruginous sandstone. It has a tendency to assume a lenticular form, now enlarging and again thinning down to a narrow seam, and while it is occasionally of vast proportions and great value (as on the north part of Tussey's Mountain), it is not so trustworthy as the thinner but more uniform and richer fossil ore of which we have already spoken.

The Levant ores of the northern portion of Tussey's Mountain form a mass of iron ore of most surprising thickness, well deserving the term by which it has been distinguished, as the "Mammoth Vein." I measured it over 20 feet in thickness on the slopes of Tussey's Mountain, at an elevation of 300 feet vertical above the fossil ore openings, and probably with about 1,000 feet of shales intervening between them; its water line is fully 600 feet above drainage. The dip is 44° to 45°. The outcrop is completely

hidden by the debris of sandstone fallen over it from the outcrop of number IV. The ore mass is extremely regular in its bedding at this place, and is perfectly conformable to the including rocks. The upper edges of the ore seams had been bent over by the denuding force which has scoured down the face of the mountains. This is well shown in the annexed section, measured by Mr. Fulton. The whole ore mass has a purplish brick-red and reddish-brown appearance, sometimes dark brown and blackish. The upper bed of about 6 feet of heavy block ore, of purplish colour, contains over 40 per cent. of metallic iron, while the middle bed of soft brick-red ore, which is esteemed the best, yields about 47 per cent. of metallic iron. Considering the facility and economy of mining, and its nearness to the fuel, the whole of this great ore mass will undoubtedly go to the furnace. The cubic contents of such a bed as this are of course immense, and might properly be called inexhaustible. As it is liable to open out at any part of this entire region, it must always be sought for with interest. Its position is never doubtful, but its outcrop is often so covered with a mass of fallen debris of white sandstone, from number IV. of the Levant series, that its search is laborious, and can never be considered complete until a cross-cut has been driven through the superincumbent masses of loose material. The wonderful outcrop of this ore on the Powel estate was found only two or three years since, as the result of a systematic search, guided by an instrumental survey, by Mr. Fulton, to whom we are chiefly indebted for our knowledge of the Levant ore.

COAL.

OF THE COALS AVAILABLE FOR THE REDUCTION OF THESE ORES.

The semi-bituminous coals of Broad Top, and of the Cumberland region in Maryland, are admirably placed with reference to the reduction of these iron ores. It is impossible to conceive anything in the order of nature more perfectly indicating means to an end. Here is a fuel yielding 60 per cent. of a hard, sonorous, metallic-looking coke, the value of which, for reducing these very ores, has been abundantly demonstrated by the operations of the Kemble furnaces at Riddlesburg, and of corresponding furnaces at Mountain Savage in the Cumberland region. The supply of this fuel is

practically inexhaustible, and obtainable at a reasonable royalty. It will be remarked that the Broad Top coalfield is about 80 square miles in area, with over 10 feet of available coal. Fifteen hundred tons of coal, one foot thick, per acre, is considered by coal viewers as a moderate estimate for bituminous coal. The coal of Broad Top is somewhat heavier than ordinary bituminous coal. On this basis 15,000 tons of coal exist in each acre; or nine million six hundred thousand tons per square mile. But to provide for coal denuded and removed, or otherwise unavailable, it will be safe to diminish this estimate by one half, giving 4,800,000 tons per square mile, or in 80 square miles there would be on this basis of estimate 384,000,000 tons of coal. Portions of this coalfield are now held by private parties, as for example, by the Kemble Coal and Iron Company, by the Powel estate and others; but much the larger part is open to purchase upon a royalty. The chief value of the calculation just made is the affirmative reply it offers to the enquiry very properly put:—"Is there coal of the right quality and in ample quantity to smelt all the vast reserves of iron ores existing upon the flanks of the mountains of this region?"

In the Cumberland region of Maryland we have over 500 square miles of the same coals which are found on Broad Top, and, fortunately, placed conveniently to approach from the lower ends of the valleys which head upon Broad Top. No estimate is attempted of the coal reserves of the Cumberland region, where the available thickness of coal is considerably greater than it is in Broad Top. If any doubt yet remained as to the supply of an adequate quantity of coals, at a cheap rate and of suitable quality, from these two conveniently situated coalfields, we have only to turn our eyes upon the great western fields of bituminous coals in the immediately adjacent counties of Pennsylvania, to see an area of coals of the most excellent quality, covering more than 12,000 square miles, —an area considerably greater than the total coal-bearing area of the United Kingdom.

Of the quantity of coal available, we may, therefore, rest assured that it is most ample and at a moderate cost. Of the quality we have the best evidence possible in the good results of the actual use of the Broad Top coals at the Kemble Co.'s furnaces at Riddelsburg.

NOTES ON
THE BRITISH IRON AND STEEL TRADES.

Presentation of Albert Gold Medal to Mr. Henry Bessemer. —On Monday, December 16, Mr. Henry Bessemer was received at Marlborough House by the Prince of Wales, when His Royal Highness, as President of the Society of Arts, presented him with the Albert Gold Medal, awarded to him by the society for the eminent services rendered by him to arts, manufacture, and commerce, in developing the manufacture of steel.

This medal has previously been awarded as follows:—

1864—Sir Rowland Hill.
1865—The late Emperor of the French.
1866—Professor Faraday.
1867—Sir W. Cooke and Sir Chas. Wheatstone.
1868—Sir Joseph Whitworth.
1869—Baron Liebeg.
1870—M. de Lesseps.
1871—Sir Henry Cole.

Prize for Steel.—The Council of the Society of Arts have resolved to offer the Society's Gold Medal to that manufacturer who shall produce, and send to the London International Exhibition of 1873, the best specimen of steel suitable for affording security in the construction of locomotives and marine engines and boilers, and for other engineering purposes.

Mineral Statistics of Great Britain and Ireland.—Since the publication of the last number of the Journal, the volume of Mineral Statistics for 1871 has been issued by Mr. Robert Hunt, Keeper of Mining Records. Referring to those portions of more particular interest to the iron and steel trades, we find that in the

year 1871 the total quantity of iron ore of which returns were received was 16,859,063 tons 14 cwts., as compared with 14,370,654 tons 18 cwts. in the previous year. The particulars are given below:—

Iron Ore Produce.

	1870. Tons.	Cwts.	1871. Tons.	Cwts.
Cornwall	11,214	4	21,947	14
Devonshire	10,193	17	14,124	14
Somersetshire	19,739	7	32,883	13
Gloucestershire	183,503	9	207,598	16
Wiltshire	101,423	0	159,894	0
Oxfordshire	38,803	17	28,330	0
Northampton	761,248	0	779,314	3
Lincolnshire	248,329	17	290,673	9
Shropshire	337,627	0	415,972	0
Warwickshire	17,500	0	34,075	0
Staffordshire, North	910,134	0	1,513,080	0
Do. South	450,000	0	705,665	0
Derbyshire	384,865	0	492,973	0
Lancashire	871,938	0	931,048	0
Cumberland	1,221,303	4	1,302,703	15
Yorkshire, North Riding	4,072,888	1	4,581,901	0
Yorkshire, West Riding	307,717	0	407,997	0
Northumberland and Durham	225,332	0	285,297	0
North Wales	59,240	0	51,887	0
South Wales and Monmouthshire	560,055	2	969,714	10
Isle of Man	...	...	75	0
Scotland	3,500,000	0	3,000,000	0
Ireland	77,600	0	107,734	0
Total iron ore production of the United Kingdom	14,370,654	18	16,334,888	14
"Burnt ore" from cupreous pyrites	...	...	200,000	0
Iron ore imported	..	...	324,175	0
Total of iron ore of which returns have been received	14,370,654	18	16,859,063	14

Pig Iron Manufacture.

The total quantity of iron ore smelted in Great Britain amounted, in 1871, to 16,859,063 tons; in 1870 the total quantity was 14,578,964 tons.

Pig Iron Produced.

	1871.	1870.
In England	4,379,370 tons.	... 3,735,627 tons.
In Wales	1,087,809 „	... 1,021,888 „
In Scotland	1,160,000 „	... 1,206,000 „
Total production of pig iron in Great Britain ...	6,627,159 „	... 5,963,515 „

Summary of Pig Iron Produce.

COUNTIES.	Tons of Pig Iron made. 1871.		Tons of Pig Iron made. 1870.
ENGLAND—			
Northumberland	34,165	...	33,623
Durham	759,244	...	676,964
Yorkshire, North Riding	1,029,885	...	916,970
Do. West Riding...	114,549	...	77,717
Derbyshire	270,485	...	179,772
Lancashire	520,359	...	422,728
Cumberland	336,569	...	255,178
Shropshire	129,467	...	112,300
North Staffordshire	268,300	...	303,378
South Do.	725,716	...	588,540
Northamptonshire	60,512	...	43,166
Lincolnshire	30,122	...	31,690
Gloucestershire ... ... / Wiltshire ... ... / Somersetshire	99,998	...	93,601
Total	4,379,370	...	3,735,627
NORTH WALES—			
Denbighshire	41,893	...	42,695
SOUTH WALES—			
Anthracite furnaces	34,761	...	28,500
Bituminous coal districts :—			
Glamorganshire	510,087	...	478,243
Brecknockshire	30,086	...	472,450
Monmouthshire	470,982	...	
Total	1,087,809	...	1,021,888
SCOTLAND	1,160,000	...	1,206,000

The following is a summary of the puddling furnaces in operation in 1870 and 1871 respectively:—

Counties.	No. of Puddling Furnaces. 1870.	No. of Puddling Furnaces. 1871.
Northumberland	54	44
Cumberland	95	89
Durham	951	1,053
Yorkshire (Cleveland district)	542	529
Do. (Leeds and Bradford district)	247	236
Do. (Sheffield and Rotherham district)	353	342
Derbyshire	94	91
Somersetshire	19	19
South Staffordshire	2,037	1,934
North Do.	429	406
Shropshire	218	206
Lancashire	154	192
North Wales	54	54
South Wales—		
Glamorganshire	613	568
Brecknockshire	86	62
Monmouthshire	553	535
Scotland	339	339
Total	6,841	6,699

The production of coal is so intimately associated with the iron trade that the statistics of coal yield cannot fail to be of interest. The figures for 1871 and 1870 are as follows:—

Summary of Coal Produce of the United Kingdom.

	1871. Tons.	1870. Tons.
Durham and Northumberland	29,190,916	27,613,539
Cumberland	1,423,661	1,408,235
Yorkshire	12,801,260	10,606,604
Derbyshire	5,360,000	5,102,265
Nottinghamshire	2,469,400	2,115,372
Warwickshire	723,600	647,540
Leicestershire	699,900	599,459
Staffordshire and Worcestershire	14,281,250	13,230,062
Lancashire	13,851,000	13,810,600
Cheshire	975,000	929,150
Shropshire	1,350,000	1,343,300
Gloucestershire	1,412,597	1,955,910
Somersetshire	673,878	
Monmouthshire	4,915,525	4,364,342
South Wales	9,120,000	9,299,770
North Wales	2,500,000	2,329,030
Scotland	15,438,291	14,934,553
Ireland	165,750	141,470
Total produce of the United Kingdom	117,352,028	110,431,192

The Henderson Fluorine Process.—The following table of results of experiments upon the Henderson Fluorine Process have been published in *Engineering*. The experiments were made at the Bowling Iron Works, Bradford. The tests were made by Mr. D. Kirkaldy. Analyses of the pig iron by Mr. E. Riley, and of the iron and steel by Dr. H. M. Noad, are also given:—

THE HENDERSON PROCESS.—The following report on experiments made at Millwall, May 7, 8, and 10, by Mr. Mattieu Williams, F.C.S., has been published in the *Engineer*:—

Report on Experiments made at Millwall, May 7th, 8th, and 10th, on Mr. Jas. Henderson's Process for the Purification of Pig Iron.—By W. Mattieu Williams, F.C.S., F.R.A.S.—(1.) All the experiments were made under the direction of Mr. Henderson, and witnessed by myself in all their stages.

(2) In each case an ordinary puddling furnace was used; the fluorspar, &c., reduced to a fine powder, were mixed and thrown upon the bed of the furnace. Some pieces of wood were laid on the powder to prevent the pigs from settling into it; the furnace was then charged with the iron and closed in the usual manner.

First Experiment, May 7th.

(3) The charge consisted of 4 cwt. of Clarence pig No. 4, with 56 lbs. fluorspar and 152 lbs. ilmenite. The furnace was not in good working order, having cooled down considerably since the previous heat.

(4) The charge was put in at 12·15 p.m. Fusion commenced at 1 p.m., and was complete at 1·30, when "boiling" commenced at once.

(5) The melted iron flowed over the powdered fluorspar and ilmenite and remained above them, the powder showing no such tendency to rise to the surface as might have been expected. The boiling was very vigorous.

(6) At 3 p.m. the boiling slackened, and the iron was found to be made and on the bottom of the furnace, the cinder floating above. The iron was balled without any puddling.

(7) The first ball was very "spongy," and what the workmen call "sulphury," *i.e.*, it ejected jets of flame during hammering. The last ball was much firmer and less flaming.

(8) The iron was rolled into a plate and a billet. I took a sample of the plate. The following are the results of analyses of the pig and plate:—

The cast steel made from the above wrought iron was analyzed by Dr. Noad for carbon only; four lots were made of the cast steel, and marked with letters for reference.

Letter A contains	... ...	·833 per cent. carbon.
,, B ,,	... ...	·860 ,, ,,
,, D ,,	... .	·600 ,, ,,
,, E ,,	... ...	·625 ,, ,,

The steel ingots were taken to Sheffield and there hammered, as there are no facilities at the Bowling Iron Works for doing it. Some hard No. 4 Bowling pig iron, which is generally used for engine tyres, being usually too hard for the other grades of iron, was also treated by Mr. Henderson. The results of the tests of the product obtained are of interest, and are given in Tables IV., V., and VI. The analysis of this parcel shows a percentage of ·450 of carbon, and 99·525 per cent. of pure iron.

LE No. IV.—Turned Bars; all marked *HF *5.

Stress.				Ratio of Elastic to Ultimate.	Contraction of Area at Fracture.	Stress per Square Inch of Fractured Area.	Extension.		Appearance of Fracture.
Elastic per Square Inch.		Ultimate per Square Inch.					At 60,000lb. per Square Inch.	Ultimate.	
lb.	tons.	lb.	tons.	per cent.	per cent.	lb.	per cent.	per cent.	
28,800	12·8	69,290	30·9	41·6	30·8	100,127	6·60	23·2	55 per cent. crystalline.
28,000	12·5	67,040	29·9	41·8	42·0	115,586	8·56	27·4	Fibrous, silky.
37,400	16·7	68,820	30·7	55·9	42·0	118,621	5·84	25·4	Ditto.
72,500	32·4	97,120	43·3	74·6	1·6	98,699	0·00	0·6	100 per cent. crystalline.
46,400	20·7	87,280	39·0	53·2	1·2	99,182	1·40	9·2	70 ditto.
49,900	22·3	67,240	30·0	74·2	0·8	60,203	0·84	2·0	100 ditto.

RESULTS OF EXPERIMENTS ON BARS OF IRON MADE BY THE HENDERSON FLUORINE PROCESS.

Analysis of Bowling No. 2 pig iron, by Mr. Edward Riley, F.C.S., No. 3, Devonshire Terrace, Kensington, London :—

	Per cent.
Graphitic carbon	3·155
Combined	·581
Silicon	1·646
Sulphur	·070
Phosphorus	·635
Manganese	1·472
Iron	92·644
	100·203

(Copy of Dr. Noad's Report.)

St. George's Hospital, Hyde Park Corner.

Sir,— . . . Although the results are, as regards the wrought iron borings, of a negative character as regards impurities, the *search* for these has not been the less lengthy. I cannot imagine a purer iron than this.

Henry M. Noad.

James Henderson, Esq., Victoria Hotel, Bradford.

Wrought Iron Borings. Received August 1st, 1872.

Carbon	0·272
Silicon	none
Sulphur	the barest traces
Phosphorus	none
Manganese	none
Iron per cent., by direct determination... ...	99·500
	99·772

Henry M. Noad, Ph.D., F.R.S.

The cast steel made from the above wrought iron was analyzed by Dr. Noad for carbon only; four lots were made of the cast steel, and marked with letters for reference.

Letter A contains	... ...	·833 per cent. carbon.
" B "	... ...	·860 " "
" D "	... .	·600 " "
" E "	... ...	·625 " "

The steel ingots were taken to Sheffield and there hammered, as there are no facilities at the Bowling Iron Works for doing it. Some bard No. 4 Bowling pig iron, which is generally used for engine tyres, being usually too hard for the other grades of iron, was also treated by Mr. Henderson. The results of the tests of the product obtained are of interest, and are given in Tables IV., V., and VI. The analysis of this parcel shows a percentage of ·450 of carbon, and 99·525 per cent. of pure iron.

TABLE No. I.—Turned Bars; all marked *HF *C.

Test No.	Description.	Diameter.	Stress. Elastic per Square Inch.		Stress. Ultimate per Square Inch.		Ratio of Elastic to Ultimate.	Contraction of Area at Fracture.	Stress per Square Inch of Fractured Area.	Extension. At 60,000lb. per Square Inch.	Extension. Ultimate.	Appearance of Fracture.
	Lot C.	Turned to in. ·564 sq. in. ·250	lb.	tons.	lb.	tons.	per cent.	per cent.	lb.	per cent.	per cent.	
G 2613	As rolled	·564 ·250	28,400	12·7	67,180	30·0	42·3	42·0	115,786	8·32	27·6	Fibrous, silky.
2615	Annealed	Ditto	28,000	12·5	66,970	29·9	41·8	44·8	121,319	8·56	28·2	Ditto.
2616	Cooled in oil	Ditto	36,200	16·2	74,610	33·3	48·5	39·2	122,711	3·02	11·4	50 per cent. crystalline.
2614	Cooled in water ...	Ditto	63,500	28·3	100,210	44·7	63·4	12·0	113,873	0·00	3·8	Fibrous, silky. 15 per cent. crystalline.
2617	Case hardened, oil ...	Ditto	45,300	20·2	84,870	37·9	53·4	7·6	100,080	1·80	10·2	90 ditto.
2618	Case hardened, water	Ditto	48,100	21·5	77,100	34·4	62·4	6·2	81,329	1·34	5·6	100 ditto.

TABLE No. II.—Ultimate Tensile Strength, etc., of One Piece of Bar, Tested as Rolled.

Test No.	Description.	Original. Diameter.	Original. Area.	Ultimate Stress per Square Inch of Original Area.		Fractured. Diameter.	Fractured. Area.	Difference. Area.	Difference. Per Cent.	Stress per Square Inch of Fractured Area.	Extension. Inch.	Extension. Per Cent.	Appearance of Fracture.
		in.	sq. in.	lb.	tons.	in.	sq. in.	sq. in.	per cent.	lb.			
G 2619	As rolled	·88	·608	57,714	25·8	·67	·353	·255	41·9	99,405	2·55	25·5	Fibrous, silky.

TABLE No. III.—Ultimate Tensile Strength of Two Pieces of Bar, Cut and Welded.

Test No.	Description.	Original. Diameter.	Original. Area.	Ultimate Stress per Square Inch of Original Area.			Difference between Welded and Unwelded Bars.					Extension. Inch.	Extension. Per Cent.		Remarks.
		in.	sq. in.	lb.	lb.	tons.	lb.	lb.	tons.	per cent.	per cent.				
G 2621	As rolled	·88	·608	55,666	55,292	2·47	2,048	2,422	1·1	3·5	4·2	1·21	12·1	10·1	Solid, clear of weld.
2620	Ditto	·88	·608	54,918			2,796			4·8		0·82	8·2		Solid.

David Kirkaldy, The Grove, Southwark Street, London, S.E., October 8, 1872.

Mr James Henderson (of New York), Tavistock Hotel, Covent Garden, W.C.

TABLE No. IV.—Turned Bars; all marked *HF *5.

Test No.	Description.	Diameter.	Stress. Elastic per Square Inch.		Stress. Ultimate per Square Inch.		Ratio of Elastic to Ultimate.	Contraction of Area at Fracture.	Stress per Square Inch of Fractured Area.	Extension. At 60,000lb. per Square Inch.	Extension. Ultimate.	Appearance of Fracture.
	Lot 5.	Turned to in. ·564 sq. in. ·250	lb.	tons.	lb.	tons.	per cent.	per cent.	lb.	per cent.	per cent.	
G 2622	As rolled	·564 ·250	28,800	12·8	69,290	30·9	41·6	30·8	100,127	6·60	23·2	55 per cent. crystalline.
2624	Annealed	Ditto	28,000	12·5	67,040	29·9	41·8	42·0	115,586	8·56	27·4	Fibrous, silky.
2625	Cooled in oil	Ditto	37,400	16·7	68,820	30·7	55·9	42·0	118,621	5·84	25·4	Ditto.
2623	Cooled in water ...	Ditto	72,600	32·4	97,120	43·3	74·6	1·6	98,699	0·00	0·6	100 per cent. crystalline.
2626	Case hardened, oil ...	Ditto	46,400	20·7	87,280	39·0	53·2	1·2	99,182	1·40	9·2	70 ditto.
2627	Case hardened, water	Ditto	49,900	22·3	67,240	30·0	74·2	0·8	60,203	0·84	2·0	100 ditto.

TABLE No. V.—Ultimate Tensile Strength, etc., of One Piece of Bar, Tested as Rolled.

Test No.	Description.	Original. Diameter.	Original. Area.	Ultimate Stress per Square Inch of Original Area.		Fractured. Diameter.	Fractured. Area.	Difference. Area.	Difference. Per Cent.	Stress per Square Inch of Fractured Area.	Extension. Inch.	Extension. Per Cent.	Appearance of Fracture.
		in.	sq. in.	lb.	tons.	in.	sq. in.	sq. in.	per cent.	lb.			
G 2628	As rolled	·88	·608	71,151	31·8	·80	·503	·105	17·3	86,004	1·74	17·4	Granular.

TABLE No. VI.—Ultimate Tensile Strength of Two Pieces of Bar, Cut and Welded.

Test No.	Description.	Original. Diameter.	Original. Area.	Ultimate Stress per Square Inch of Original Area.			Difference between Welded and Unwelded Bars.					Extension. Inch.	Extension. Per Cent.		Remarks.
		in.	sq. in.	lb.	lb.	tons.	lb.	lb.	tons.	per cent.	per cent.				
G 2629	As rolled	·88	·608	37,516	25,254	11·3	33,635	45,896	20·5	47·3	64·5	0·15	1·5	0·8	Weld, clear.
2630	Ditto	·88	·608	12,993			58,158			81·7		0·00	0·0		Weld, burned.

David Kirkaldy, The Grove, Southwark Street, London, S.E., October 8, 1872.

Mr. James Henderson (of New York), Tavistock Hotel, Covent Garden, W.C.

Clarence Pig No. 4.		Plate.
Combined carbon	0·440	0·300
Graphitic carbon	2·790	Trace.
Silicon	2·333	0·070
Sulphur	0·005	Trace.
Phosphorus	0·910	0·092
Manganese	0·750	0·330
Calcium	Trace.	0·060
Iron by difference	92·772	99·148
	100·000	100·000

Second Experiment, May 7th.

(9) The charge consisted of 4 cwt. of Clarence pig No. 4, 56 lbs. fluorspar, and 56 lbs. ground fire-brick.

(10) In at 4·20 p.m.; complete and balls out at 6·25 p.m. The furnace was now in good working condition, and the action much more rapid than in the first experiment. The boiling was so vigorous that there was a considerable overflow from the rabble-hole.

(11) The iron was formed without puddling on the furnace bottom, as before, the fluid cinder completely covering it.

(12) The balls presented the same appearance, and behaved under the hammer in the same manner as those of the first experiment.

(13) I took a ladle sample from the furnace about half an hour after complete fusion. Its composition is as follows:—

Combined carbon	2·600
Graphitic carbon	Traces?
Silicon	0·120?
Sulphur	Trace.
Phosphorus	0·180
Manganese	0·550
Calcium	0·100
Residue insoluble in nitric acid	4·100

(14) This, and the other ladle samples—described in the following (20) (26)—presented a difficulty in analysis on account of the quantity of entangled cinder. I might have separated this cinder by re-fusion in a crucible, and analysing the button, but this course

was open to serious objection, inasmuch as such a button would have represented the iron in a further stage of manufacture due to this re-fusion. There would have been a notable difference in the proportion of carbon, for I have found that whenever iron containing much carbon is re-melted or even re-heated in contact with the atmosphere, there is a considerable loss of carbon. This oxidation of carbon appears to take place with more than usual rapidity in the unfinished iron made by Mr. Henderson's process—see (29). The quantity of silicon would be also diminished by combustion, and probably some of the sulphur and phosphorus simultaneously removed. Besides this, there is considerable risk of contamination from the crucible and fuel when thus operating on small quantities of iron. On the other hand, the method I used, viz., of selecting the central and soundest part of the ladle button, and regarding the insoluble residue as cinder, renders the determination of the graphite and silicon doubtful, and they are accordingly marked "?" This is unimportant in reference to practical questions, inasmuch as the elimination of silicon is a very easy problem, and that of graphite usually inevitable. The sulphur and phosphorus are correctly represented as they existed at that stage of the process. The importance of correctly representing the combined carbon in these analyses will be seen hereafter.

Third Experiment, May 8th.

(15) The charge consisted of 4 cwt. of Millom pig, 56 lbs. fluorspar, and 56 lbs. ground fire-brick. In at 3·55 p.m., out at 5·30 p.m.

(16) The following is the composition of the pig that was used :—

Combined carbon	1·280
Graphitic carbon	2·550
Silicon	2·825
Sulphur	0·095
Phosphorus	0·072
Manganese	Trace.
Iron by difference	93·178
	100·009

(17) The boiling was very vigorous, with overflow. The iron formed on the furnace bottom, as before, without puddling.

(18) The balls were still drier and more flaming than in the first and second experiments. The first ball very spongy, the second and third much firmer. This difference was more marked than before, and it appears to be one of the characteristics of the iron made by Mr. Henderson's process that at each successive stage of further exposure to the air and further working it increases in firmness in an unusual degree; so much so, that the ball of the first experiment, which presented so unpromising an appearance under the hammer, produced a finished iron of very extraordinary tenacity, as shown by Mr. Kirkaldy's tests.

(19) I took four ladled samples from the furnace. No. 1, 15 minutes after complete melting; No. 2, 25 minutes after melting; No. 3, 35 minutes after melting; No. 4, 45 minutes after melting; and determined the combined carbon of each. The results were so remarkable that I had three additional determinations made by my assistant. The results of all four, with average, are stated below in percentages:—

Number of sample.	First determination.	Second determination.	Third determination.	Fourth determination.	Average.
1	2·90	2·98	2·96	3·06	2·97
2	3·00	3·00	3·02	3·00	3·00
3	3·00	3·00	3·00	3·02	3·00
4	2·80	2·83	2·81	2·80	2·81

(20) Analyses of the first and third of these gave the following results:—

	First.	Third.
Combined carbon	2·97	3·00
Graphitic carbon	Traces?	Traces ?
Silicon	0·150?	0·120 ?
Sulphur	0·090	0·060
Phosphorus	0·034	0·029
Manganese	Trace	Trace
Calcium	0·080	0·075
Residue insoluble in nitric acid	4·300	4·00

Fourth Experiment.

(21) Charge, 4 cwt. Millom pig; 54 lbs. fluorspar, 56 lbs. ilmenite; 28 lbs. red ore; 30 lbs. black oxide of manganese.

(22) In at 4·28 p.m, Time of melting, 1 hour 20 minutes. Balls out at 7·15 p.m.

(23) The dryness and flaming of the balls like Experiment 3.

(24) I took four ladle samples as in Experiment 3. The first at 12 minutes after complete fusion; the second at 22 minutes, the third at 32 minutes, and the fourth at 42 minutes after fusion.

(25) The carbon determinations being as remarkable as those of Experiment 3, they were repeated in like manner with the following results, stated in percentages of combined carbon:—

Number of sample.	First determination.	Second determination.	Third determination.	Fourth determination.	Average.
1	2·60	2·85	2·80	2·83	2·77
2	2·80	2·80	2·80	2·82	2·80
3	1·60	1·70	1·61	1·60	1·63
4	2·00	2·00	2·00	2·00	2·00

(26) The following are the results of further analyses of the first of the above ladle samples, and of a piece cut from the first ball when under the hammer:—

	First ladle sample.	First ball.
Combined carbon	2·77	0·49
Graphitic carbon	Traces?	Trace.
Silicon	0·156?	0·075
Sulphur	0·085	0·015
Phosphorus	0·033	0·026
Manganese	0·610	0·450
Residue insoluble in nitric acid	4·200	—

(27) The behaviour of these and the other balls under the hammer led me to suppose that the first of each heat was more highly charged with carbon than those which followed. I determined the carbon of the first and third balls of this experiment, and found that the first contained 0·94 per cent. combined carbon, the second 0·29 per cent. combined carbon.

(28) This difference explains the difference of firmness. I may mention that Bessemer steel, containing as much as 0·94 per cent. of combined carbon, is usually quite rotten under the hammer. In order to bear such an amount of carbon and be workable it requires to be made of unusually pure pig iron.

(29) I have made many comparative determinations of the carbon contained in different balls from the same heat of puddled

steel, and have always found it greatest in the first ball, but never before found so great a difference as that shown above. The blazing of the balls is doubtless mainly due to combustion of carbon, and I infer that one of the peculiarities of the iron made by Mr. Henderson's process, viz., its great improvement at each successive stage of working, is due to the gradual elimination of carbon, and probably also of silicon, by combustion. I suspect that the greater dryness of the first ball is due to the presence of unoxidised silicon in the place of the silicic acid or silicates of ordinary puddled iron or puddled steel, and that this silicon becomes oxidised and removed as the working of the iron proceeds.

(30) While the experiments were in progress I urged Mr. Henderson to allow the puddler to work the iron a little. The practical ironworkers who witnessed the first experiment all agreed with me in believing that by this means the iron would be made more quickly, and its quality and quantity much improved. Mr. Henderson, however, resisted on the ground that his object in these experiments was merely to show the action of the chemicals he used. With the results of the above analyses before me, I now see the wisdom of this course, as it has brought out the important characteristic chemical features of Mr. Henderson's invention, although it may not have displayed his process to the best practical advantage as regards rapidity, economy, &c.

(31) It has clearly shown in the first place that iron or mild steel may be made from either good or inferior pig in a puddling furnace by simple chemical action, unaided by the usual mechanical work of puddling.

(32) The persistence of the carbon (19) and (25), in spite of the vigorous boiling, is a remarkable feature not easily explained. In the ordinary course of puddling there is a progressive decrease of carbon, and it is customary to attribute the "making," or infusibility of the iron which renders it separable from the cinder, mainly to this and the oxidation of the silicon.

(33) That there should be less oxidation of the carbon than in puddling was to be expected, inasmuch as the covering of cinder prevented atmospheric oxidation; but those who have studied the puddling process most carefully are now pretty well agreed in attributing much, if not most, of the oxidation that occurs during boiling to the oxygen derived from the reduction of the oxides of the fettling.

An abundance of red ore was used in these experiments, and other oxygen-bearing compounds were added in the first and fourth experiments (3) (21). Comparing the carbon in (19) with that in (25) there is some difference, apparently due to the fact that only fire-brick was used with the fluorspar of the third experiment, while ilmenite, hematite, and black oxide of manganese, were used in the fourth experiment. Still the amount of progressive oxidation even in this case was remarkably small, and it must be remembered that in all cases—especially in experiment 2 (10), where only fire-brick was mixed with the spar—the boiling which is usually, and I believe justly, attributed to the evolution of carbonic oxide, was very violent.

(34) With the few facts at present before me, I cannot venture to offer any explanation of the boiling that occurred in these experiments; but, from the colour of the flame and other abnormal appearances, I suspect that the gases evolved are very different from those given off by the jets of an ordinary puddling charge.

(35) The most important and characteristic feature of this process is the fact that, simultaneously with the persistence of carbon, a steady elimination of silicon, sulphur, and phosphorus is going on. Oxidation cannot account for this. Some other action essentially different from any that is made available in any of our ordinary and even extraordinary processes of purification of pig iron is going on.

(36) In all the processes that have been successfully worked, and in nearly all that have been attempted, the removal of the phosphorus and sulphur (and in a certain degree of the silicon) has only been effected simultaneously with the removal of the carbon. To this I have—in a paper published in *Nature*, Aug. 18, 1870—attributed the fact that it has hitherto been found impossible to produce useful steel directly from ordinary British pig iron containing any notable proportion of sulphur and phosphorus—especially of the latter.

(37) I there stated that "*no process has yet been discovered by which these impurities can be removed without at the same time removing the carbon in corresponding degree,*" and that "I put this in italics because I am convinced by experience of its great practical importance; because I do not find it clearly and distinctly enunciated in any general or special treatise; and, further,

because I have seen so plainly that the want of clearly understanding it is the rock upon which so many unfortunate inventors have split."

(38) I had not then heard of Mr. Henderson's process. The results of the above-described experiments and analyses lead me to suspect that the difficulty which then appeared insuperable may now be solved, though further experiments are necessary to establish this conclusion, the importance of which can scarcely be over-estimated.

(39) Had I expected such results I should have proceeded somewhat differently—should have especially taken ladle samples from the first and second experiments, where a pig containing so much phosphorus was used.

(40) It now appears to me very desirable to take a number of such samples at different stages, and to determine the carbon, sulphur, and phosphorus of each without re-fusion. By this means it may be firmly decided whether the results obtained by the above described experiments and analyses are to be relied upon as uniformly attainable and essential characteristics of this process. If so, we may safely conclude that Mr. Henderson has succeeded in making a very important forward step in the manufacture of iron.

(41) A puddling furnace was used because it was there and available, although, in many respects, obviously very unsuitable for this process. On this account I do not consider that the questions relative to the cost of fuel, yield of finished iron, &c., were tested at all, and, therefore, cannot report anything respecting them.

Three-High Rolls.—The paper read by Mr. Lauth at the Glasgow meeting, upon this subject, led to a rather long discussion at the time, and, since then, Mr. Alex. L. Holley has brought the subject under the notice of the American Institute of Mining Engineers. The following is an abstract of his communication:—

A characteristic, and, to Americans, an amusing discussion of the three-high rail mill, arose out of the reading of Mr. Lauth's paper on three-high plate mills, at the Glasgow meeting of the Iron and Steel Institute.

From the report of the meeting in the English papers, it appears that Mr. Menelaus, the celebrated rail-maker of Dowlais, could not wait for the discussion of Lauth's plate mill, but launched at once

into the British objections to the three-high rail mill, which is quite another matter.

The American mill, which is very different in principle and arrangement from the mill used abroad, appears never to have been understood by foreigners, although many of them have observed its working, during the last fifteen years, in our various iron and steel works. American ironmasters certainly do not complain of this oversight, much as they may wonder at it.

Mr. Menelaus, Mr. Snelus, and Mr. Williams prefer the two-high mill for the following alleged reasons:—

1. It requires a smaller stock of rolls, as compared with the three-high mill.

2. The section of American rails is not uniform on the two sides, due to the fact that the top and middle rolls in a three-high mill are movable, while the bottom roll is fixed.

In order to test the value of these objections, it will be necessary to observe the difference between the English and the American mill.

In the American mill the top and bottom rolls are deeply grooved, and the middle roll is nearly plain—*i.e.*, the middle roll, answers as a cover or lid to the grooves of the other rolls. The piece enters groove No. 1 between the bottom and middle rolls, and so on above and below the middle roll, to the end. There must of course be a slight space between the groove and its cover, that is to say, between the collars of the upper and lower rolls and the collars of the middle roll, and into this space a fin of metal is squeezed out at each pass. If this space always occurred at the top of the groove, or always at the bottom of the groove, the fin would be increased at each pass, and ultimately spoil the rail. It is necessary to reverse the position of this fin at each pass, and this is just what the American three-high mill does. The grooves open alternately upwards and downwards. In grooves No. 2, the top of the flange comes against the solid body of the roll, and no fin forms. But the bottom of the flange occurs at the opening between the top and middle roll, and here a fin forms. On the next pass, No. 3, the fin that was formed on the bottom of the flange is smoothed out by coming in contact with the solid body of the lower roll, and a fin forms at the top, which fin is, in turn, smoothed out by No. 4 groove, and so on to the end. At the same

time the rail is not turned over; the flange is always at the right. This feature is essential in rolling, not only rails, but beams and all finished bars that require closed grooves.

Now in the English three-high mill, the bottom and middle rolls are grooved, instead of the bottom and top rolls. The grooves all open upwards, instead of alternately upwards and downwards. Hence, to smooth out the fin left at the top of the flange by pass No. 2, the rail must be turned over before it enters pass No. 3, in order to bring the fin in contact with the solid body of the bottom roll. The rail must be turned over after each pass, with hooks and tongs and hard work, while in the American mill it is simply caught on the hooks and entered just as it comes out.

The English mill also requires much more length of roll for a given number of passes. The rolls shown are of the same length, but the American mill has seven passes, while the English has but five. This is due to the fact that in the latter mill the plain roll —in this case the top roll—forms a cover to the grooves of one of the grooved rolls only, that is, of the middle roll. Enough space has to be taken out of the middle roll to form the covers for the grooves in the bottom roll. In the American mill, however, the middle roll forms the cover for the grooves in both the grooved rolls.

The question now arises, why is the English form of mill used? With collared rolls and deep box grooves, it is necessary to employ a guide, which is a sort of chisel, lying in the groove like a turning tool, to peel the piece out of the groove. Otherwise the side friction of the collars against the piece would wind it round the roll. When the three-high mill was first introduced abroad, it seems to have been supposed that the guide must lie in the groove by gravity—that it could only be applied to the top of a roll. Hence the bottom and middle rolls must be grooved, for on the top of these rolls the piece passes. The Messrs. Fritz, of Pennsylvania, however, did not take this for granted. They saw the immense advantages of the grooved top roll, instead of the grooved middle roll, and they at once devised the very simple expedient of a hanging guide to peel the piece out of the bottom of the groove in the upper roll. But a guide in the bottom of a groove will fall out—then it must be held in—and what more simple and durable device for this purpose can be imagined than

the counterweight, affording a uniform pressure on the roll, and capacity to yield to its inequalities. We have read that for the want of a horse-nail an army was lost; for the want of an almost equally small and obscure piece of iron—a hanging guide—our English friends have lost, and ever persist in not finding, the signal advantages of the grooved top roll—the advantage of not turning the piece over at each pass, and the advantage of shorter rolls for a given number of passes.

We can now understand why Mr. Menelaus, having, as he states, an acre of two-high rolls of different patterns, objected to the three-high mill, on the ground that it would give him an acre and a half. The three-high mill he really criticises has but five passes in a given length; the mill he meant to criticise has seven in the same length, and this fact alone places the American three-high mill nearly on a par with the two-high in respect of number of spare rolls required.

But this is not all; taking beams and miscellaneous bars, as well as rails, the length of roll to be changed, in order to go on another pattern, is actually less in the three-high than in the two-high mill. This arises from the fact that in the three-high, the same groove is in most cases used twice over.

In a common form of American three-high rail rolls, two roughing grooves are worked over and over, making four passes, and three are worked once, equal to seven passes in five grooves. One finishing groove is worked over and over, and four are worked once, equal to five passes in five grooves. If a groove and its collars occupy 8 in. length of roll, the total length of three roughing and three finishing rolls will be 240 in. In a two-high mill having the same number and size of passes, the total length of all the rolls will be 208 in., or about 87 per cent. of the length required in the three-high mill. To off-set this slight increase in the amount of rolls used, the three-high mill presents very great advantages over the old form of two-high mill with rolls moving continuously in one direction. 1st. It turns out twice as much product in a given time, since in the two-high mill the piece returns over the top roll without getting any reduction. 2nd. It keeps the piece the same side up, while the two-high mill requires it to be turned over at each pass. All the grooves open upward, and in order to prevent the fin from growing on the top of the flange, the rail must be turned over so

as to come against the solid body of the bottom roll. 3rd. The piece in the two-high mill has to be dragged over the top roll, while in the three-high mill it is forced back by the rolls.

As compared with the reversing two-high mill, the American three-high has the advantage of keeping the piece the same side up all the time, thus increasing the product, and decreasing the strain on the men. The reversing mill, with either the clutch or the reversing engine, is a much more costly machine to construct and maintain than the three-high mill connected directly to the engine. It works somewhat more slowly than the three-high, and the impression among experts is, that it is less economical of steam.

As we have observed, the three-high mill requires less changing of rolls for miscellaneous purposes. In beam-making, its advantages are most conspicuous. Orders for beams are always smaller than for rails—often less than a turn's work—so that the rolls must be often changed. American millmen can hardly understand how beams can be produced with profit, when these heaviest of rolled masses have to be turned over at each pass, and when a quarter more than the necessary weight of rolls has to be shifted for each order.

We now come to the second objection to the three-high mill. As stated by Mr. Williams, it is, that accuracy in the section of a rail is "utterly impossible" in the three-high mill, and that this is due to the fact that the bottom roll is fixed, while the other two are movable. Mr. Snelus attributes the inaccuracy, not to the three-high mill, but to the fact that the middle roll is not fixed; and he states that in a three-high mill with fixed middle roll and movable top and bottom rolls, he has seen just as accurate rails produced as in the English two-high mill.

This objection is entirely without foundation. The inaccuracies of section mentioned must have, and may easily have, arisen from other causes, one of them being that American rail makers do not dress off their rolls as often as English makers do. Again, the middle roll is sometimes improperly set end-wise, and is allowed to have end-play.

In respect of shape of groove, the two-high and three-high mills are precisely alike. Rolling a rail in a three-high mill is just the same as rolling it in two two-high mills. The shape and relation of the grooves in the bottom roll and the roll above it, in the two-

high mill and in the three-high mill, are identical. The shape and relation of the grooves in the top and middle rolls of a three-high mill are identical with the shape and relation of the grooves in a two-high mill. Remove the top roll and you have left a two-high mill, differing in no respect, as far as the shape and relations of the finishing groove are concerned, from a two-high mill. The finishing groove shapes the rail. Now to say that taking away the top roll, which does not touch the rail on the finishing pass, will alter its shape, is at least amusing.

In the last paragraph, the author deals with the statement that the inaccuracy in working arises because the middle roll is movable and the bottom roll fixed. This explanation would not, however, be clear without diagrams.

Probability of Coal being found underneath Liverpool.—A paper on this subject has been read before the Liverpool Geological Society, by Mr. G. H. Morton, F.G.S., Hon Sec. of the Society. After stating the opinions of geologists and mining engineers, tending to show that coal has long been supposed to underlie the new red sandstone of Lancashire, Cheshire, and other parts of England, and showing the formations occurring in Denbighshire, Flintshire, Cheshire, and South Lancashire, on the Government Geological maps, the author proceeded: At the close of the carboniferous period, I believe that the whole of the country I am describing was covered by a continuous deposit of coal measures, with the underlying millstone grit and carboniferous limestone in an undisturbed position. Some idea of the enormous denudation that has taken place may be obtained from the fact that all these carboniferous strata, 6,700 feet in thickness, have been denuded from off the Wenlock shale of Denbighshire and Flintshire. It is a geological truism that lines of elevation are lines of weakness and waste, and that mountains crumble away when exposed to sub-aerial action for geological ages. Lines of depression, on the contrary, are lines of strength and durability, for the rocks are then buried and protected from denuding agencies. In this manner the carboniferous strata, which once covered the high land of North Wales, have been swept away, and only scattered patches of the limestone at the base left to indicate their former position; while more to the north-east there has been less elevation, and conse-

quently such a reduced denudation, that a fringe of coal measures occurs along the south-west of the Dee. Still further to the north-east, in Wirral, the gradually increasing depression brings in the new red sandstone overlying the coal measures, which seem to be fully developed and undenuded below it. The coal measures continue in this relatively depressed condition until thrown up to the east of Liverpool, where the Trias and Permian have been denuded from off them. Assuming that the middle, or productive coal measures underlie the new red sandstone in the country around Liverpool, the question is, whether we can reach the coal, and whether there is a fair chance of success in trying to obtain it. So far, no one has tried with sufficient capital and knowledge of the subject to have had any chance of doing so. Many attempts have certainly been made, principally in the keupers, marls, and sandstones, 2,000 feet above the coal measures, by persons who thought that they were boring in the coal strata till they discovered their mistake and abandoned their undertaking. In the event of a boring being made in search of coal below the Trias, it would be desirable to select a spot where the strata have been denuded, and where the pebble beds, or lower sandstones of the Bunter formation, occur at the surface. The lower Bunter is considered to be 400 feet thick, but as its base is not known with any certainty in any section nearer than Sutton, no reliance can be placed on this estimated thickness; besides, it may vary considerably if the coal measures present a denuded surface. If, on the contrary, there has not been any material denudation, the thickness must be uniform, or nearly so. Assuming the lower Bunter to be 400 feet thick, and that there is no Permian below it, the coal measures at Grange and Eastham, in Wirral, and under Crown-street, Liverpool, must be very near the surface—perhaps only 300 feet below it—but there is a great probability of the Permian occurring above the coal measures, and these would be the upper series, in which there are no workable coal seams. Although there are many spots favourably situated for an experimental boring, any person who undertakes the task must be prepared to run the risk of finding a few hundred feet of Permian strata, without the remotest chance of obtaining the slightest information on the subject, except what he obtains during the operation. He must be prepared for 1,200 feet of upper coal

measures—red strata, which colliery engineers never like—though they may not be so thick as supposed. If there has been little denudation of the coal measures before the deposition of the Permian, it seems probable that, with the base of the pebble beds at the surface, the upper coal measures would be reached at 800 feet, and the middle or productive measures at 2,000 feet—*i.e.*, taking an average of probabilities, but no attempt should be made with a pecuniary object unless the projectors were able to bore a few hundred feet deeper if necessary. Coal might, certainly, be reached at a much less depth than 2,000 feet, but, as a set-off against that chance, there is a great probability of having to go lower still, and a possible chance of not finding coal at all. The mere depth, however, does not present much difficulty, for there are several coal pits that are worked as far below the surface, but there was little or no risk in opening those collieries, for the existence of a particular coal seam at a calculated depth must have been known beforehand. But the great difficulty is to obtain the first experimental boring, for if that were successful in reaching coal, an important section of the superincumbent strata would be obtained, from which very momentous conclusions might be deduced. If, for instance, there were Permian and upper coal measures with no apparent denudation, the thickness of these formations would be known, and it would be safe to assume that the same conditions extend under a considerable area of the country around Liverpool. Under such a regular succession of the formations, the depth of the workable coal seams of the Prescot and Flintshire coalfields, beneath the new red sandstone, might be approximately ascertained. But if, on the other hand, a coal seam in the productive series were found directly under the Trias, although the undertaking might be a profitable speculation in itself, there would be much doubt and uncertainty about the result of any other boring that might be made at a distance from the first, so that the general result would be far less satisfactory; for if the coal measures were faulted and irregularly denuded before the new red sandstone was deposited over them, each explorer would gain little from the experience of his predecessors, but would have to take his chance and be content with the result —coal or no coal, as might happen. In conclusion, I think that I have demonstrated that there is a valuable coalfield beneath our

feet. It would be easy to prove it absolutely for about £2,000; but it is a question whether it is worth any person's while to do so—perhaps it deserves the attention of large landowners and colliery proprietors.

The Coal and Iron Mines of the Arigna District of the Connaught Coal Measures, Ireland.—A paper was read on this subject before the Geological Section of the British Association for the Advancement of Science, at Brighton, by Mr. T. A. Readwin, F.G.S.—It is well known that the Connaught coal measures occupy portions of the counties of Roscommon, Sligo, and Leitrim, in the province of Connaught; and of county Cavan, in the province of Ulster; and that Lough Allen, near the source of the navigable river Shannon, forms a basin nearly in the centre of the Roscommon and Leitrim coal and iron district.

The Arigna District lies a little to the west of Lough Allen, in Co. Roscommon, about 10 miles north-east of the town of Boyle, and has been generally known as the southern and western divisions of the Connaught coalfield. For convenience of description this coalfield may have the following sub-divisions:—

I. The Aghabehy, or Southern Coalfield.
II. The Altagowlan, or North-Western Coalfield.
III. The Seltenaveeny, or North-Eastern Coalfield.

I.—*The Aghabehy Coalfield* embraces the coal in the townlands of Aghabehy, Tullytawen, Rover, Carrownault, Derrinavogey, and Kilronan Mountain, occupying an undulating plateau at a range of 650 to 950 feet above the level of the sea.

The third or top coal seam has been removed from this division by denudation; the middle is the only seam worked, its thickness varying from 18 inches to 33 inches. It has a slate roof, and is separated from the bottom or "crow coal" by beds of sandstone, ranging from 20 feet on the southern slope to 55 feet on the northern slope of the mountain; there being, in the latter case, occasional beds of shale. The "crow coal" varies in thickness from four to thirty inches. The outcrop of these two seams can be accurately traced round the slopes of the mountain in the above-named townlands.

II.—*Altagowlan Coalfield.*—This field, which occupies a portion of the N.W. sub-division, will probably yield a considerable quantity of valuable coal.

In it can be seen the outcrop of all *three* seams of coal. The top seam is inferior in quality, but useful for calcining purposes. It is practically 18 inches thick. The middle seam, as in Aghabehy, has been worked, and is 20 inches thick.

Between this field and that of Seltenaveeny to the E. there are at least two well-defined faults, with downthrow to the E., bringing the coal down about 450 feet in the distance of one mile and a quarter.

III.—*Seltenaveeny Coalfield.*—Some of the shafts were sunk through the top seam, which in every case was found to be about 18 inches in thickness, to depths of 100 to 120 feet.

The middle seam, 24 to 34 inches thick, which has been rather extensively worked in the north part of this townland, close to the boundary of the County Leitrim, yields some of the best coal in the district.

The coal area of the Arigna district may be fairly taken at about 1,000 acres, containing about 2,000,000 tons of workable coal, and the coalfields, when properly opened, are capable of yielding 80,000 to 100,000 tons per annum.

The bituminous coal and ironstone of this district are of the true coal measures, and they correspond exactly with the "Mountain Mines," or lower coal measures, or Gannister beds of Lancashire. They are literally the Gannister or lower coals, all the beds having a floor of what Mr. Binney calls Gannister, and penetrated by *Stigmaria ficoides.*

Sir R. Kane, in his "Industrial Resources of Ireland," gives several analyses of the bituminous coal of this district, from which it appears that the mean average of carbon is about 80 per cent. The coal of the entire district may be taken to be of similar composition, subject only to local changes, which do not extend over any considerable area.

In the opinion of Mr. George Greenwell, of Poynton, and Mr. John Marley, of Darlington, Mining Engineers (August, 1872), "The middle seam of coal is of excellent quality; not only working large to two-thirds of its produce, but is well adapted for gas and coke making. Section of this seam varies from 18 to 33 inches of good coal; but taken over the whole extent, we consider 20 inches a fair basis for calculation. Also Bandystone, or Canal coal, say from 24 inches. Coal, good Blocker, 1 foot; Holing, 8 inches. Gannister Thill."

Analyses of the Arigna Coal.

	1.	2.	3.
Pure coke	66·15 ...	65·87 ...	74·89
Volatile matter ...	23·10 ...	19·10 ...	17·70
Ashes	10·75 ...	15·03 ...	7·41
	100·00	100·00	100·00
Equal to pure carbon	77·00	77·00	84·00

The elementary composition would average :—

Carbon	79·69	to	81·04
Hydrogen	6·24	to	4·91
Oxygen	3·52	to	6·64
Ashes	10·75	to	7·41
	100·00		100·00

By analysis (1872) the coal contained 77 per cent. of carbon.

The "Clay Ironstone" occurs in shales, underlying the coal in bands of from half an inch to more than twelve inches in thickness, with ironstone nodules (called, locally, "Bullocks") intervening. The quantity in any given area is not large, still, judging from the experience of former workings and in numerous sections along the banks of the Arigna River and its tributary streams, there are several tracts available which will yield, say, 2,000 to 3,000 tons of ironstone per acre in a single working (*i.e.*, 12 inches thick and 4 feet high, equal to 25 per cent. of cubical area). In some places more than one workable band will be available in the same area; and, without being able to estimate the quantity of ironstone quite so easily as the coal, it is quite evident that the ironstone measures extend over a greater number of acres than the coal seams. It is found most abundantly in the zone of shales between 200 and 300 feet above the limestone. In quantity the ironstone may be said, with Sir R. Griffith and others, to be "practically inexhaustible."

The quality of the ironstone is very superior, yielding a higher percentage than most of the English, Welsh, or Scotch clay ironstones. It yields from 35 to 45 per cent. of raw ore, or 45 to 58 per cent. of calcined ore, or say 50 per cent. on the average; worth at the present time 7d. per unit, or about 28s. per ton.

Analyses of the Clay Ironstone.

In 1850, Mr. Mitchell assayed six samples of the ironstone of the Arigna district, and certified as follows:—

No. 5 yields	41 per cent. of cast iron.		
No. 1 ,,	43	,,	,,
No. 4 ,,	46·5	,,	,,
No. 6 ,,	46·8	,,	,,
No. 2 ,,	50	,,	,,
No. 2, *calcined*	74	,,	,,

No. 2, on analysis, contained—

Protoxide of iron	51·653
Peroxide of iron	3·742
Oxide of manganese	·976
Alumina	1·849
Magnesia	·284
Lime	·410
Potash	·274
Sulphur	·214
Phosphoric acid	·284
Carbonic acid	31·142
Silica	6·640
Carbonaceous matter	2·160
	100·00

Analyses of the Nodules of Ironstone.

	No. 1.	No. 2.	No. 3.
Protoxide of iron ...	53·65	54·42	51·52
Lime	—	2·23	0·69
Magnesia	—	2·02	1·55
Alumina	1·00	1·43	—
Insoluble clay	12·43	8·65	15·50
Carbonic acid	32·92	31·25	30·74
	100·00	100·00	100·00
Metallic iron	41·70	42·30	40·00

Analyses of the Bands of Ironstone.

	No. 4.	No. 5.	Average of all.
Protoxide of iron ...	47·28	49·94	51·36
Lime	1·26	3·75	1·59
Magnesia	2·23	3·79	1·92
Alumina	1·59	0·87	0·98
Insoluble clay	18·46	9·08	12·82
Carbonic acid	29·18	32·57	31·33
	100·00	100·00	100·00
Metallic iron	37·70	38·80	40%

Average, 40 per cent. of metallic iron.

The mean of five analyses of the clay ironstone nodules from Arigna gave—

Protoxide of iron	51·36
Lime	1·59
Magnesia	1·92
Alumina	0·98
Insoluble clay	12·82
Carbonic acid	31·33
	100·00

and this contains 40 per cent. of metallic iron.

The usual loss by calcining the iron remaining as protoxide should be 31·33 per cent., and the calcined ore should, of 100 parts, consist of—

Iron	58·2
Oxygen...	16·6
Lime and magnesia	5·1
Clay	20·1
	100·00

The Arigna ironstone does not suffer by comparison with other well-known ores of the same class as to its yield of metallic ores; for example :—

The "Black Band" of Scotland, from	8 samples,	gave an average of	33·28	per cent.
The Clay Ironstone of Yorkshire from	3 ,,	,,	31·70	,,
,, Derbyshire	,, 3 ,,	,,	28·93	,,
,, Staffordshire,	10 ,,	,,	35·72	,,
,, Cleveland (at Middlesbrough)		,,	35·46	,,
,, ,,	7 other places	,,	32·84	,,

Again, making a comparison in another way, we have of metallic iron—

		Natural State.	Calcined.
Richest Arigna Iron Ore	Irish.	43·3	61·4
Poorest ,,	Irish.	37·7	53·2
Average ,,	Irish.	40·0	58·0
Average Kilkenny	Irish.	38·7	55·3
Richest Staffordshire	English.	40·5	60·0
Poorest ,,	English.	28·0	40·0
Richest Welsh	Welsh.	42·1	60·0
Poorest ,,	Welsh.	31·4	44·7
Ordinary Glasgow	Scotch.	31·6	45·8
Mushet's Black Band	Scotch.	41·0	63·1

The ironstone occurring for the mostpart in land of comparatively little value, it is available to a great extent, at a small cost; and, probably, hydraulic mining could be brought effectively to bear upon the shattered shales containing the ironstone, as it would not be difficult to get a head of 400 feet of water to work the richest places.

The stone coal and slack could all be utilised in the calcination of the ironstone, and its percentage of metallic iron raised as seen above. In that improved state it could be sent to furnaces, where it would always find a ready market.

The small coal can also be readily converted into coke, for which there is always a great demand at a high rate.

The coal and coke, and raw or calcined ore, can be inexpensively transported to the deep western shore of Lough Allen, thence by steamer through the Leitrim Canal to Carrick-on-Shannon or Drumsna; thence by Midland Great Western Railway Company along their well managed line as far as Dublin, or to the port of Sligo, on the Atlantic Ocean.

Although the present high price of coal is no criterion as to its future value, yet, whilst Ireland imports three millions of tons of coal per annum (Dublin and Belfast taking nearly a million tons each), it is an extraordinary fact that the quantity of coal annually raised in Ireland, practically, may be written down *nil.*

Under the present totally altered circumstances both of coal and iron, in my opinion the Connaught coal and iron measures ought to be vigorously and scientifically worked immediately.

South Wales Institute of Engineers.—The address of the president—read at the last annual meeting—has been published. Referring to the iron trade, he states that not very many years ago, it was considered good work for a blast furnace to turn out 100 tons of iron with an expenditure of from three to five tons of coal per ton of iron. Coke ovens were then unknown, hot blast had not been introduced, and the waste gases of the furnace were not utilised. Now furnaces produce from 200 to 300 tons of pig iron per week, with an expenditure of fuel of about 25 cwt. per ton of iron. Rolling mill machinery has been vastly improved of late years. Direct-acting engines, working expansively, have taken the place of the old cumbrous beam engines, and the costly mistake of driving several

trains of rolls, and the multifarious machines of a rolling mill by one central engine, has been found out and corrected in the newer mills.

The transactions contain a paper by Mr. Robert Bond, on "Keyless Railway Chairs." These chairs have been in use on the Sirhowy Railway since December, 1870, and have been subjected to severe tests. The results are said to have been most satisfactory, not even a single bolt having to be re-adjusted during the whole period.

The Institute passed a vote of condolence to the representatives of the late Mr. Joshua Williams, who found for the South Wales trade a cheap way to London and Liverpool for their coal and iron; he greatly improved the railway facilities of the district, and he took an especially active part in getting rid of the broad gauge for South Wales.

[Mr. Joshua Williams will be remembered by many members of the Institute, in connection with the railway facilities afforded the Society on the occasion of their visiting Merthyr in 1870.]

CLEVELAND IRON PRODUCTION.—The production of Cleveland pig iron in the North of England, as taken from the statistics issued monthly by the Cleveland Ironmasters' Association, was, in the years 1871 and 1872, as under:—

	Tons. 1872.	Tons. 1871.
January	160,567	151,826
February	155,672	141,068
March	168,685	161,049
April	163,408	155,472
May	168,795	164,082
June	162,207	155,912
July	162,603	158,126
August	162,808	157,053
September	161,028	152,857
October	171,316	163,027
November	165,822	160,307
December	166,061	163,460
	1,968,972	1,884,239

The number of blast furnaces erected at 31st December, 1872, was 137, of which 130 were blowing; the same date in the previous year 131 furnaces were built, 124 of which were at work. Nineteen new furnaces are in course of construction.

THE SCOTCH IRON TRADE.—The following official statistics have been published relative to the production and stock of Scotch iron for the last 28 years. The number of furnaces in blast at the end of each year is also given:—

Furnaces in Blast on		Make. Tons.	In		Stock on
				160,000...	Dec. 31, 1844
Dec. 31, 1845...	88...	475,000...	1845...	245,000...	„ 1845
„ 1846...	98...	570,000...	1846...	149,000...	„ 1846
„ 1847...	100...	510,000...	1847...	80,000...	„ 1847
„ 1848...	103...	580,000...	1848...	98,000...	„ 1848
„ 1849...	112...	690,000...	1849...	210,000...	„ 1849
„ 1850...	105...	595,000...	1850...	270,000...	„ 1850
„ 1851...	112...	760,000...	1851...	350,000...	„ 1851
„ 1852...	113...	775,000...	1852...	450,000...	„ 1852
„ 1853...	114...	710,000...	1853...	210,000...	„ 1853
„ 1854...	117...	770,000...	1854...	120,000...	„ 1854
„ 1855...	121...	825,000...	1855...	98,000...	„ 1855
„ 1856...	128...	832,000...	1856...	88,000...	„ 1856
„ 1857...	123...	915,000...	1857...	160,000...	„ 1857
„ 1858...	132...	945,000...	1858...	295,000...	„ 1858
„ 1859...	125...	950,000...	1859...	330,000...	„ 1859
„ 1860...	131...	1,000,000...	1860...	427,000...	„ 1860
„ 1861...	121...	1,035,000...	1861...	535,000...	„ 1861
„ 1862...	125...	1,080,000...	1862...	645,000...	„ 1862
„ 1863...	134...	1,160,000...	1863...	756,000...	„ 1863
„ 1864...	134...	1,160,000...	1864...	760,000...	„ 1864
„ 1865...	136...	1,164,000...	1865...	652,000...	„ 1865
„ 1866...	98...	994,000...	1866...	510,000...	„ 1866
„ 1867...	112...	1,031,000...	1867...	473,000...	„ 1867
„ 1868...	121...	1,068,000...	1868...	568,000...	„ 1868
„ 1869...	129...	1,150,000...	1869...	620,000...	„ 1869
„ 1870...	126...	1,206,000...	1870...	665,000...	„ 1870
„ 1871...	126...	1,160,000...	1871...	490,000...	„ 1871
„ 1872...	115...	1,090,000...	1872...	194,000...	„ 1872

BOARD OF TRADE RETURNS.—The Exports of IRON and STEEL from the United Kingdom during the year 1872, as compared with these for 1870 and 1871, have been as under :—

IRON.

		1870. Tons.	1871. Tons.	1872. Tons.
PIG	To Germany	126,178	203,284	313,477
	,, Holland	156,879	246,092	349,405
	,, France	92,441	71,265	90,200
	,, United States	113,980	190,183	193,957
	,, Other Countries	263,861	346,634	385,687
	Total	753,339	1,057,458	1,332,726
BAR, ANGLE, BOLT, AND ROD	To Germany	11,511	15,007	17,783
	,, Holland	10,197	8,376	8,407
	,, France	4,137	766	1,363
	,, Italy	33,127	33,040	19,533
	,, Turkey	11,645	11,176	7,408
	,, United States	50,538	64,301	64,995
	,, British North America	38,939	45,146	46,868
	,, ,, India	29,855	27,472	16,093
	,, Australia	12,507	12,393	20,865
	,, Other Countries	118,999	131,407	110,561
	Total	321,455	349,084	313,876
RAILROAD OF ALL SORTS	To Russia	207,676	78,367	106,305
	,, Sweden	2,933	10,918	12,272
	,, Germany	52,660	50,287	50,275
	,, Holland	15,466	14,868	9,026
	,, France	372	2,653	2,120
	,, Spain and Canaries	13,195	13,199	11,010
	,, Austrian Territories	38,434	24,260	7,988
	,, Egypt	2,333	16,759	14,472
	,, United States	421,824	512,277	472,760
	,, Spanish West India Islands	3,709	3,848	2,315
	,, Brazil	5,890	20,519	20,710
	,, Peru	13,843	29,262	34,874
	,, Chili	17,273	11,130	2,845
	,, British North America	36,291	61,961	77,248
	,, India	153,137	34,523	14,652
	,, Australia	8,691	14,691	25,091
	,, Other Countries	65,665	81,675	83,585
	Total	1,059,392	981,197	947,548
WIRE OF IRON OR STEEL (except Telegraph Wire) galvanised or not		23,447	26,200	33,605
HOOPS, SHEETS, AND BOILER & ARMOUR PLATES	To Russia	11,253	17,334	11,968
	,, Germany	9,837	14,406	15,968
	,, Holland	8,290	8,570	9,813
	,, France	3,109	2,008	3,168
	,, Spain and Canaries	4,757	5,145	6,049
	,, United States	39,228	41,520	31,448
	,, British North America	11,980	16,229	16,027
	,, India	16,342	15,871	18,308
	,, Australia	13,515	13,928	20,273
	,, Other Countries	63,173	65,326	75,401
	Total	181,484	200,337	208,423

		1870		1871		1872.
		Cwts.		Cwts.		Cwts.
TIN PLATES ...	To France	25,158	...	42,469	...	66,207
	,, United States ...	1,507,455	...	1,738,587	...	1,747,205
	,, British North America	59,759	...	84,002	...	80,039
	,, Australia	63,006	...	102,823	...	101,926
	,, Other Countries ...	341,641	...	424,235	...	369,307
	Total	1,997,019	...	2,392,116	...	2,364,684
		Tons.		Tons.		Tons.
CAST OR WROUGHT AND ALL OTHER MANUFACTURES (EXCEPT ORDNANCE UNENUMERATED)	To Russia	21,134	...	14,608	...	18,779
	,, Germany	17,035	...	25,051	...	28,673
	,, Holland	5,677	...	12,217	...	13,642
	,, France	4,433	...	4,359	...	5,127
	,, Spain and Canaries ...	5,916	...	4,158	...	5,714
	,, United States	9,661	...	10,671	...	13,444
	,, British North America	12,376	...	16,245	...	21,603
	,, Possessions in South Africa	2,321	...	2,380	...	3,692
	,, India	35,082	...	29,499	...	20,327
	,, Australia	19,388	...	18,694	...	23,588
	,, Other Countries ...	100,698	...	107,416	...	115,025
	Total	233,721	...	243,298	...	269,614
IRON, Old, for re-manufacture		106,749	...	139,812	...	108,181

STEEL.

UNWROUGHT... ...	To France	2,221	...	1,764	...	2,935
	,, United States	17,787	...	21,133	...	24,051
	,, Other Countries ...	14,954	...	16,292	...	18,299
	Total	34,962	...	39,189	...	45,285
MANUFACTURES OF STEEL OR STEEL AND IRON combined		11,175	...	13,038	...	11,130
TOTAL OF IRON AND STEEL		2,825,575	...	3,169,219	...	3,388,622

Nº1

SOUTH

Nº 2

Nº 3

SOUTH

Nº4

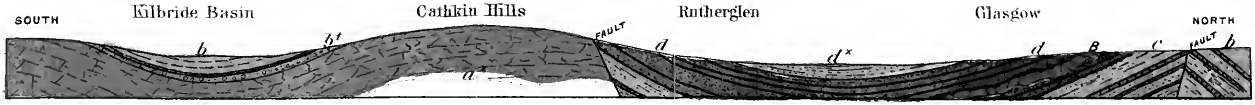
SOUTH WEST

Wallace

a

No. 1. TO ILLUSTRATE MR GEIKIE'S PAPER ON THE GEOLOGICAL POSITION OF THE COAL & IRONSTONE BEARING STRATA OF THE WEST OF SCOTLAND. See Page 8 (August, 1872)

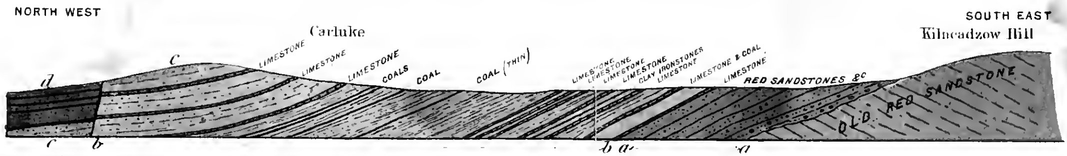
Diagrammatic Section across Lanarkshire Coal-fields showing general disposition of the strata (details omitted) length of section about 13 miles



a^x Bedded Volcanic Rocks in position of Calciferous Sandstone Series — b Carboniferous Limestone Series. — b^t Volcanic Tuff &c of "Limestone" age
c Millstone Grit Series — d Coal Measures — d^x Red Sandstones (Upper portion of Coal Measures
B Intrusive Basalt Rock (Limestone Series underneath Glasgow and Rutherglen probably resting on Volcanic Rocks like those of Cathkin Hills

No. 2.

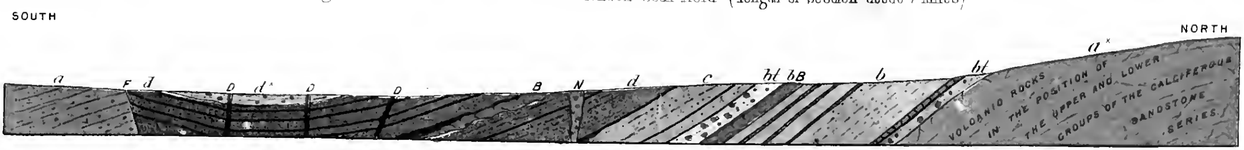
Diagrammatic Section across Carluke Limestone and Ironstone Field (details omitted) length of section about 3½ miles



a Calciferous Sandstone Series (Upper or Oil-shale group wanting;) b Carboniferous Limestone Series, — c Millstone Grit; d Coal Measures

No. 3

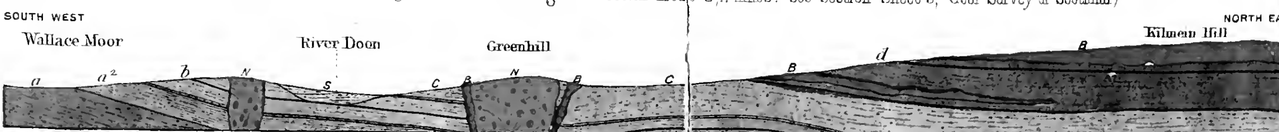
Diagrammatic Section across Kilmarnock Coal-field (length of section about 7 miles)



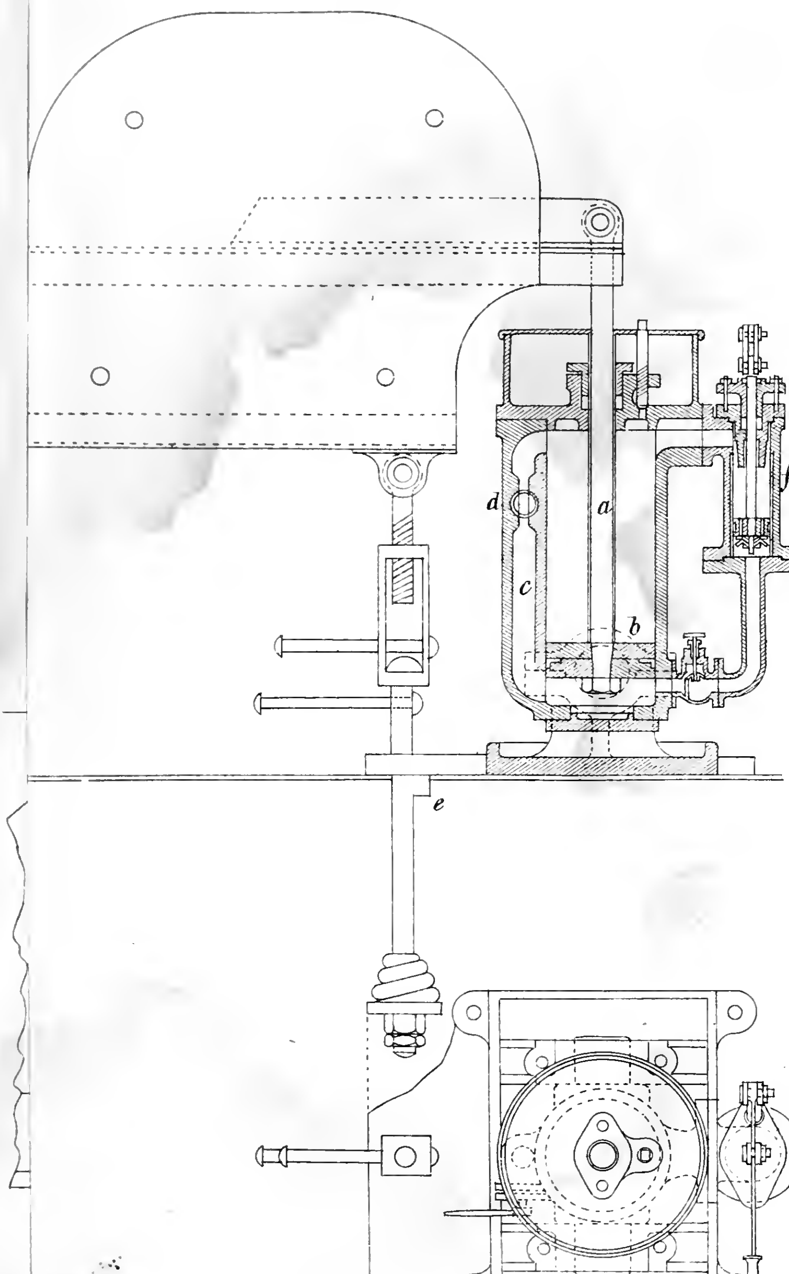
a Red Sandstones of Calciferous Sandstone Series. a^x Volcanic Rocks in position of a and a^2 (See Section No 4) b Limestone Series. c Millstone Grit
d Coal Measures. — d^x Upper Red Sandstones unconformable upon d but part of Coal Measure Series; — bB Basalt-rock and bt Volcanic Tuff both of Carboniferous Limestone age. N Volcanic Agglomerate in Neck or Vent of Permian age; — D. Dykes of Basalt-rock of Miocene age, F. Fault

No. 4

Section across Dalmellington Coal field. (length of Section about 3½ miles. See Section Sheet 5, Geol Survey of Scotland)

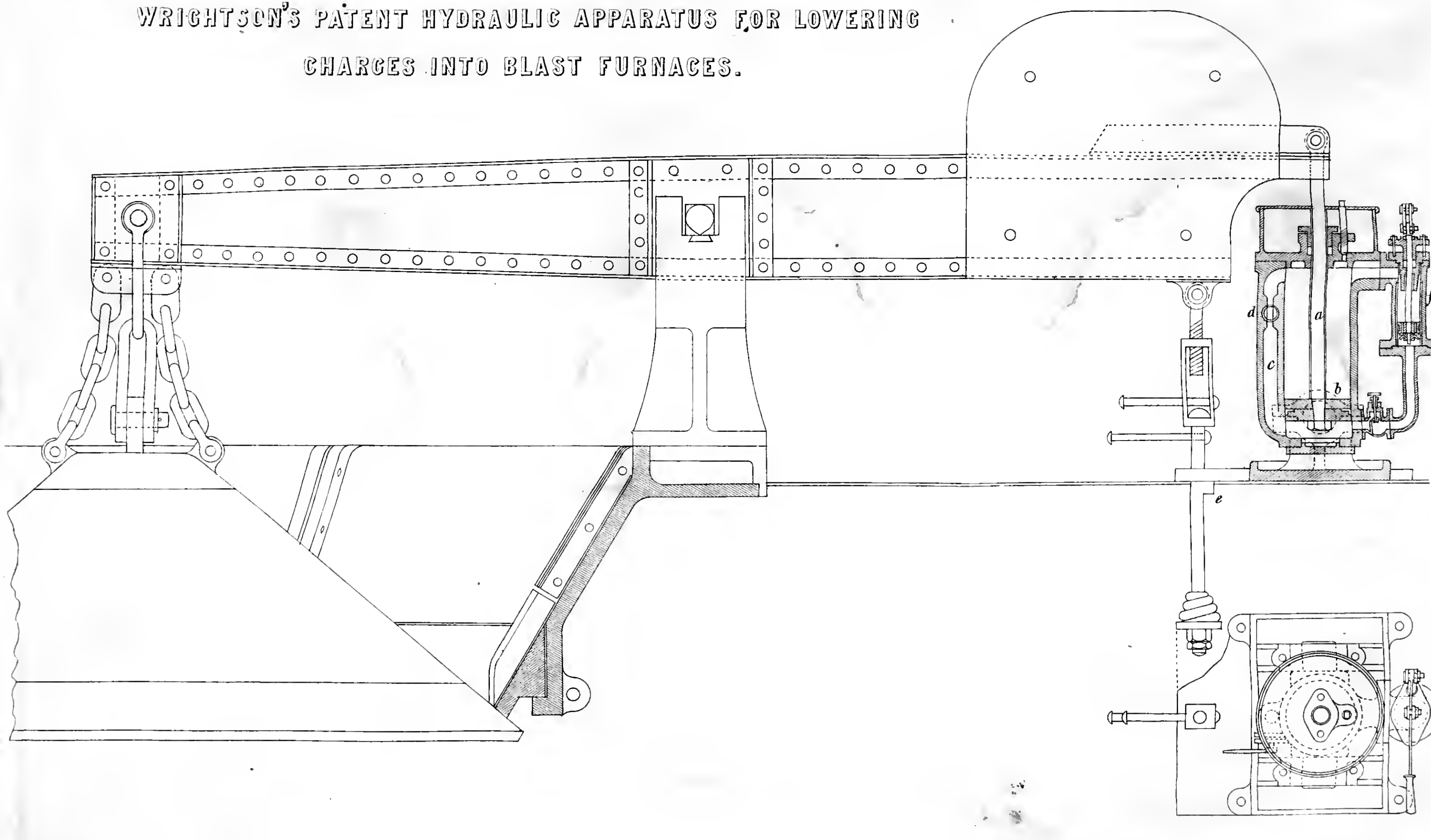


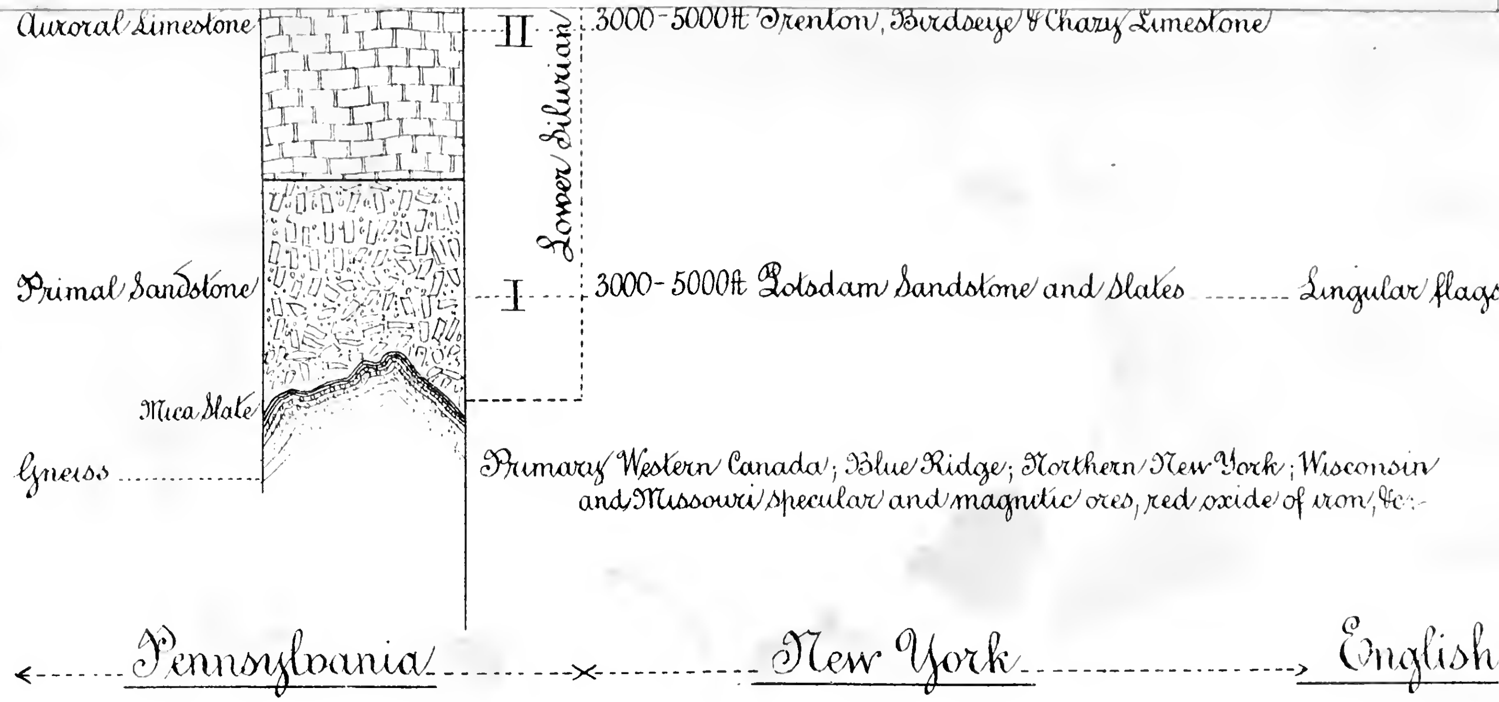
a Red Sandstones &c — a^2 Shales and Cement-stones (a and a^2 = Calciferous Sandstone Series, b, Carboniferous Limestone Series, — C, Millstone Grit
d Coal Measures — B Intrusive Basalt-rocks; — N. Volcanic Agglomerate filling up Vents of Permian age; S, Superficial Deposits



d
a
c
b
f
e
f

WRIGHTSON'S PATENT HYDRAULIC APPARATUS FOR LOWERING CHARGES INTO BLAST FURNACES.





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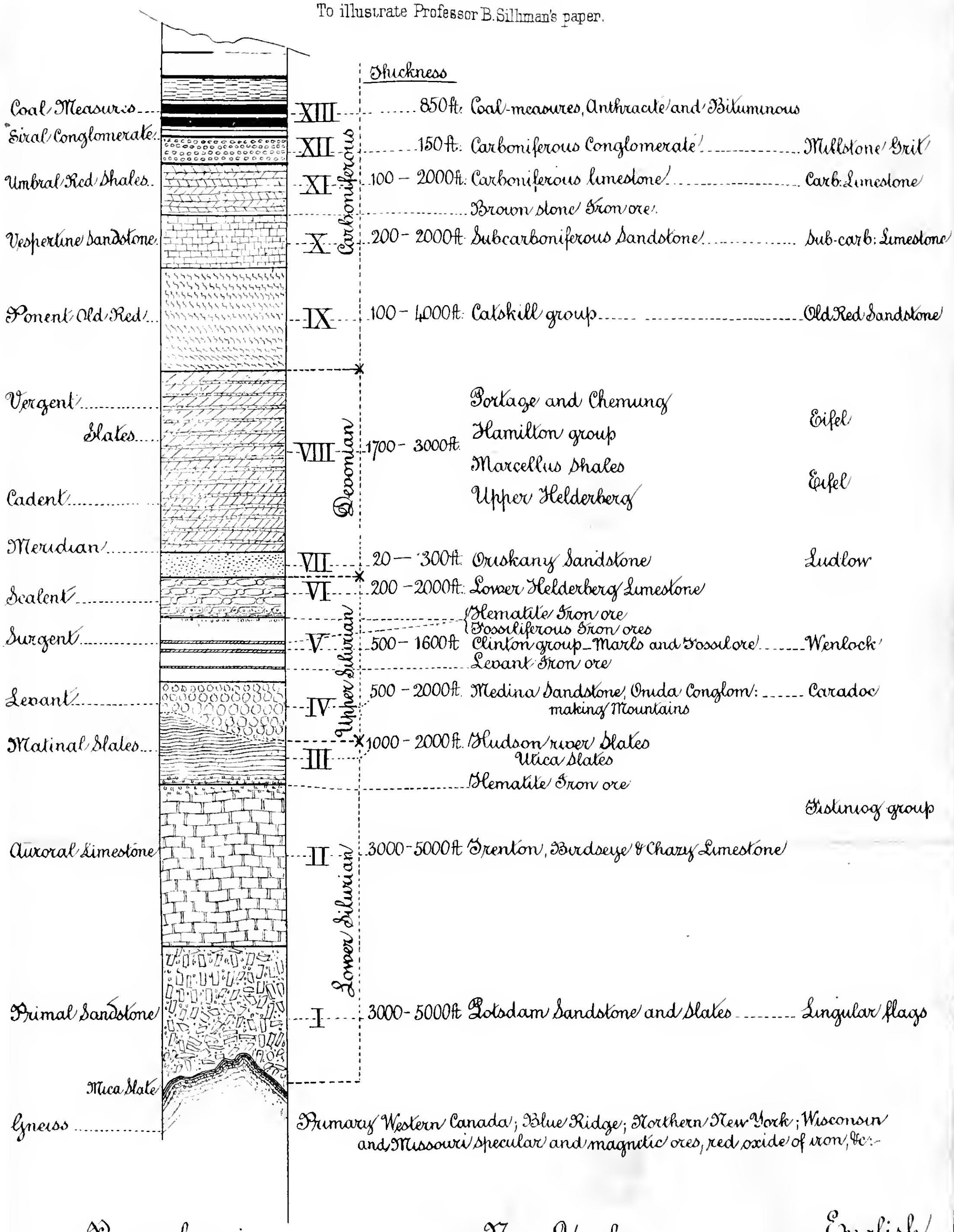
Vertical Section exhibiting the formation in the Palæozoic Strata of Pennsylvania with their New York State and English equivalents.

To illustrate Professor B. Sillman's paper.



Journal of the Iron & Steel Institute

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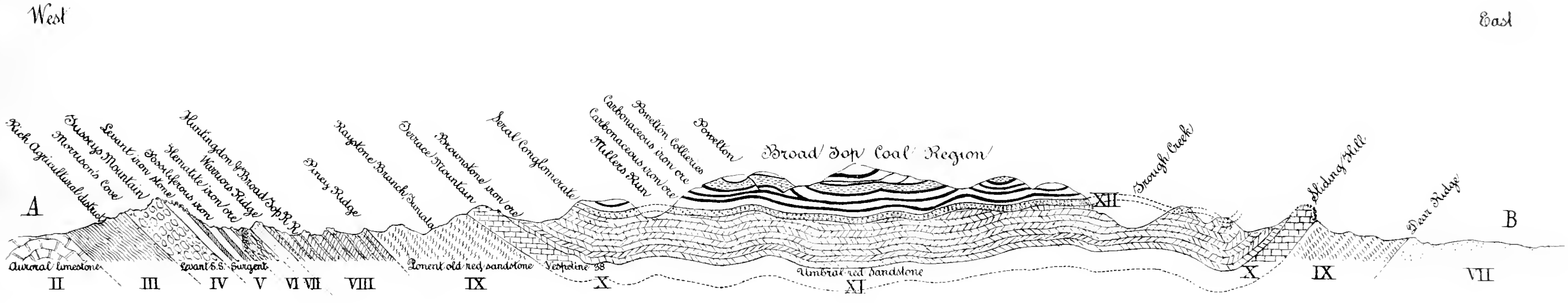
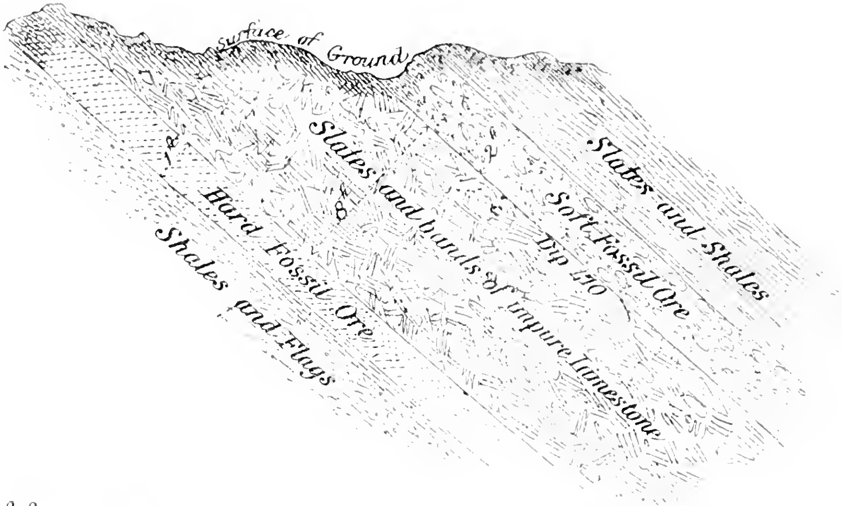
Journal of the Iron & Steel Institute



Geological Section of the Broad Top Coal and Iron Region
Exhibiting the relative positions of the Coal and Iron Ore in
Huntingdon and Bedford Counties _ Penn.

Enlarged from State Report and recent discoveries added



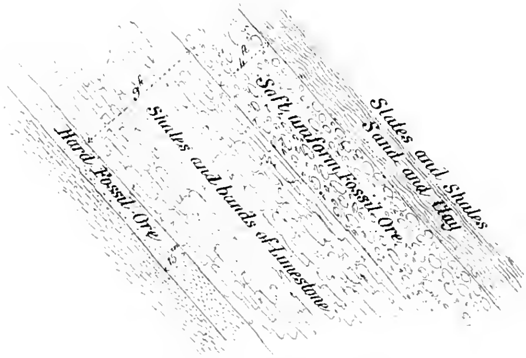
Section of Fossiliferous Iron Ores at surface of land, west of Coffee Run in Estate of Powel

M & M W Lambert Newcastle

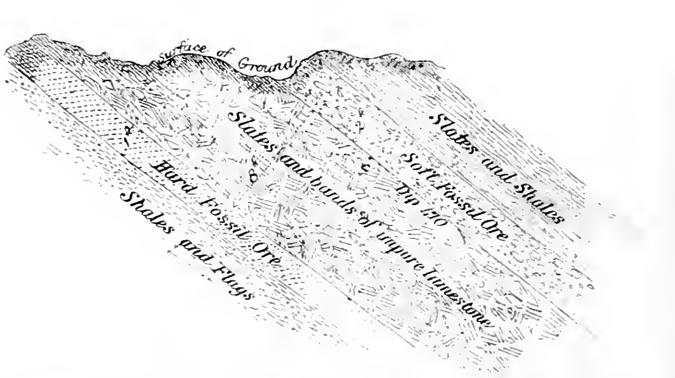
To illustrate Professor B Silliman's paper

III

Section in Kemble Coal and Iron Co's Mine near Tatesville. _ 130 feet below Outcrop

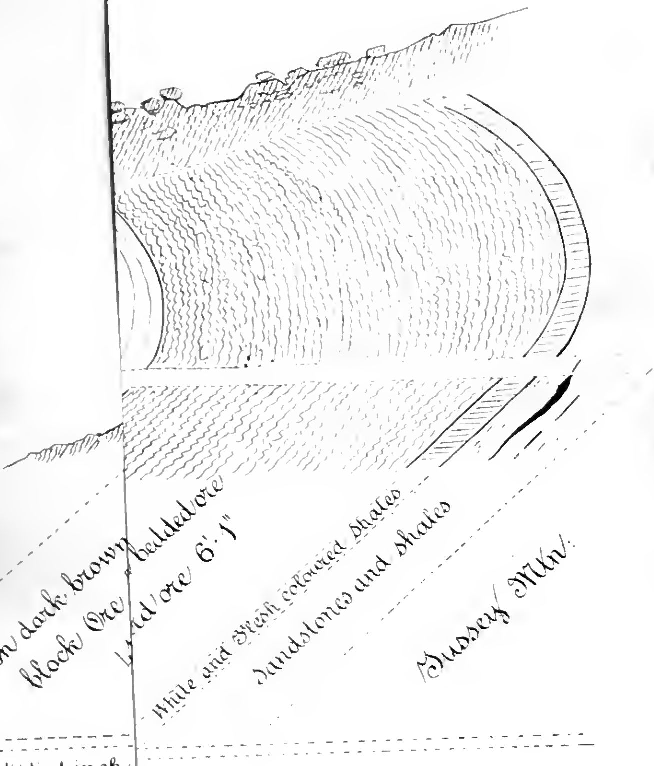


Section in Hopewell Furnace Mine, Yellow Creek, 80 feet beneath Outcrop



Section of Fossiliferous Iron Ores at surface of land, west of Coffee Run in Estate of Powel

West of Coffee Run

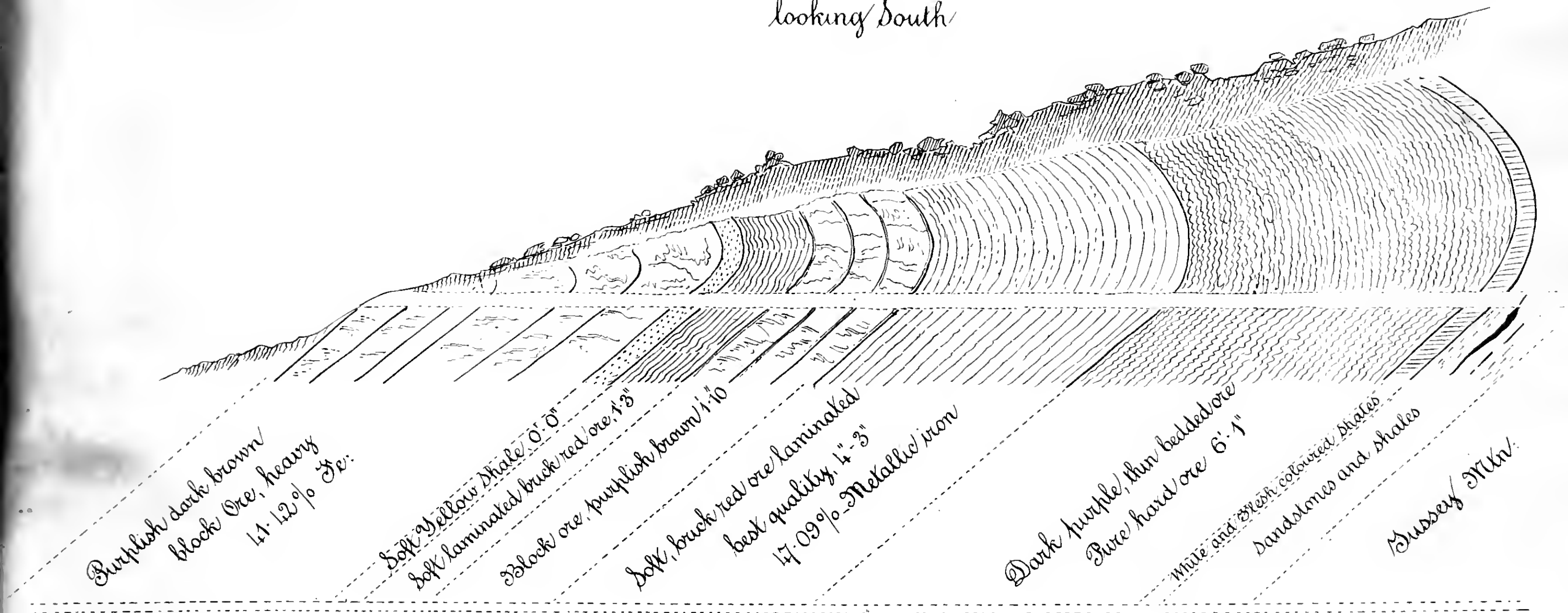


cale 4 feet to 1 inch

Section of Mammoth triple deposit of Levant iron ore, West of Coffee Run

To illustrate Professor B. Silliman's paper

looking South



Scale, 4 feet to 1 inch

Total thickness of Seam 20 feet 1 inch

M & M W Lambert, Newcastle